E-TYPE REPEATERS

E6 REPEATER

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CHAPTER 1

INTRODUCTION

1.01 The E6 repeater is a new, transistorized voice repeater designed to reduce the transmission losses of exchange-area trunks. Generally, the field of application is that of the present E23 repeater. The initial cost of the E6 is comparable to that of the E23, but the ease of installation and adjustment is markedly better. The performance of the repeater is also superior, providing lower net loss circuits with higher return loss on cables which are of good quality; that is, free of irregularities of loading and pair make-up. The repeater requires only 48-volt unfiltered central-office battery, has low power consumption, and takes only about half the bay space of an E23 repeater.

1.02 Transmission gains up to 12 db can be provided by the E6 as an intermediate repeater. How much of this can be used in specific cases is determined mainly by the return loss of the lines involved and is nearly uniform for any cable endsection from zero to almost full section. Direct-current supervisory signals and most low-frequency signaling currents are passed by the E6 without serious impairment and without the aid of auxiliary bypassing equipment. The only exception is signaling for panel-incoming revertive signals, which are not passed successfully. Voice-frequency signaling is amplified the same as voice currents.

1.03 The E6 is not simply a transistorized version of the present electron-tube E23 repeater. While the E6 employs negative-impedance converters as the E23 does, the over-all principle of operation is substantially different. In the E23 repeater, the impedance of the repeater is made to match the "book" value of cable-pair impedance by the use of adjustable networks of resistors, inductors, and capacitors. To provide the desired gain and impedance characteristics, these elements are interconnected by means of wires (called straps) soldered to their terminals. In the E6 repeater, the impedance-matching function is performed by a passive network separate from the gain unit. Once the passive line building-out network (LBO) has been adjusted, the gain can be varied in small steps without readjustment of the matching network. All adjustments are made by tightening or loosening screws to close or open electrical contacts. No strapping or soldering is required.

1.04 The E6 is not a universal replacement for the E23 because it is at present usable only with some of the more common types of loaded exchange-area cable facilities. No arrangements are yet available for using E6's with nonloaded facilities.

1.05 The superior performance of the E6 repeater is obtained through adjusting each line building-out network to fit the associated cable pair. Where this adjustment is made by measurement, circuit net losses up to 1 db less than with an E23 repeater can be obtained. Where the practice is to specify all screw settings by examination of the circuit layout rather than by measurement, the results, on the average, will be but little better than with E23 repeaters. Test sets are available to make these adjustments, and it is emphasized that the adjustments for gain or for impedance match are a fast, simple process, in no way comparable with the labor of strapping E23 repeaters.

1.06 The E6 repeater, unlike the E23, can do a good job at the ***junction*** of two different kinds of cable or of loading. However, it cannot be used to full advantage on sections composed of mixed gauges, mixed cable capacitances, or irregular loading.

CHAPTER II

DESCRIPTION

1. Major Characteristics of E6 Repeater

Type: 2-wire voice-frequency, transistorized

Power: 48-volt unfiltered central office battery, 35 ma.

Gain: 1 to 12 db* (adjusted by screws)

Endsections: Adjustable for 0 to 5800 feet

Overload: +8 vu output for speech or music
+16 dbm output for single-frequency power

Maximum metallic direct current in line windings: 60 ma.

Temperature Ranges:

For service, the repeater itself should not be colder than 0°F and not hotter than 140°F.

For shipping and storage, the surroundings should not be colder than −40°F or hotter than 150°F.

Number of repeaters per 23-inch bay:
156 with no test jacks
144 with test jacks
102 with disablers and no test jacks
96 with test jacks and disablers

Suitable for:

Line side	
H88-loaded high-capacitance cable	
19, 22, or 24 gauge	830A LBO network
H88-loaded low-capacitance cable	
19 gauge	830B LBO network
D88-loaded high-capacitance cable	
19 or 22 gauge	830B LBO network
Terminal side	832A LBO network

Test Sets Required:
54A transmission measuring set
54B test stand
54C return-loss measuring set

*Adjustments are published in 0.5 db steps, but finer adjustments are practicable.

2. Equipment Description

2.01 This chapter gives general descriptive information for the E6 telephone repeater.

2.02 The repeater assembly consists of a shell in which is mounted an 831A network (gain unit) and *two* line building-out (LBO) networks.

2.03 The 830A LBO network is designed for high-capacitance 19-, 22-, or 24-gauge cable with H88 loading; the 830B is designed for low-capacitance 19-gauge cable with H88 loading, or high-capacitance 19- or 22-gauge cable with D88 loading. The 832A network is a dummy LBO which simply provides a 2-wire path from one side of the gain unit to one of the line connections of the shelf plug. A terminal repeater uses an 832A network on the office side and an 830A or 830B on the other. An intermediate repeater uses two 830A or 830B networks or one of each type.

2.04 Each LBO network is secured in the repeater by tightening four screws. These networks can be replaced to convert the repeaters from intermediate to terminal operation (or vice versa) or to use the repeater on other type facilities. Fig. II-1 shows an assembled terminal repeater equipped with an 830A and an 832A network.

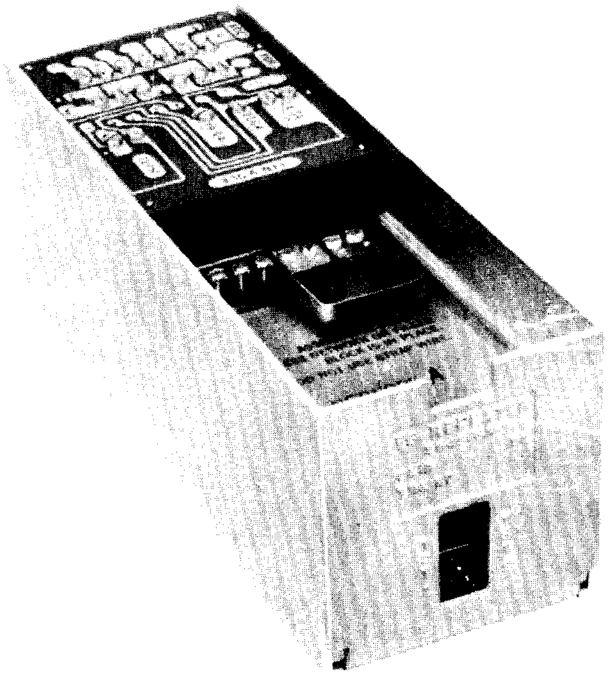


Fig. II-1

2.05 Fig. II-2 shows the plug (rear) end of the repeater with one LBO network removed.

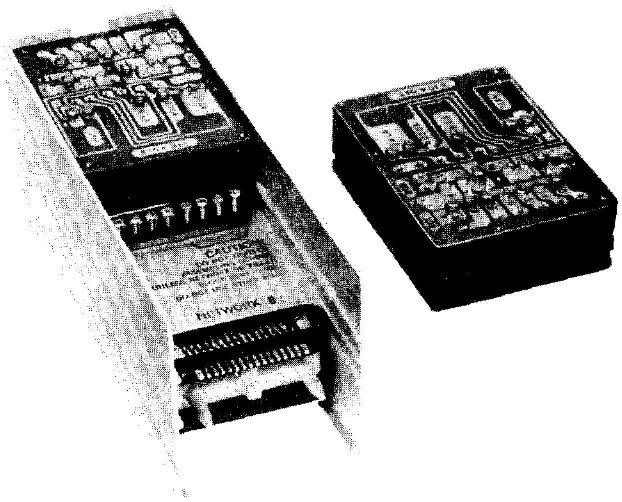


Fig. II-2

2.06 Fig. II-3 shows an 831A network. The adjusting screws are accessible on the lower side of the repeater. The 831A network gain unit is the transistorized active part of the circuit. It uses 48-volt unfiltered battery supply. Each repeater requires 35 ma. Regular positive grounded office battery is satisfactory. This network can easily be removed from the repeater shell for replacement.

2.07 Fig. II-4 shows the open-eyelet terminals that hold the 830A network in place and provide electrical connections.

2.08 Fig. II-5 is an exploded view of an intermediate repeater, showing the insulating block that holds the 831A network in place.

2.09 The front cover or door of the repeater, when opened, acts as an extracting tool to release the repeater plug from the shelf connector, enabling the repeater to be removed from the shelf. This is shown in Fig. II-6.

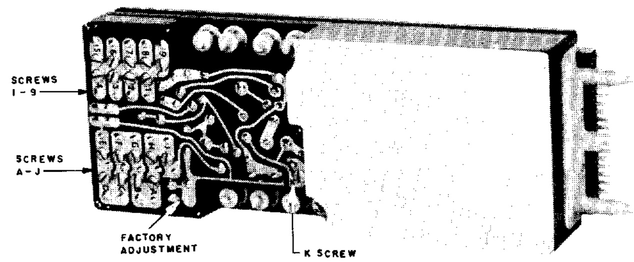


Fig. II-3

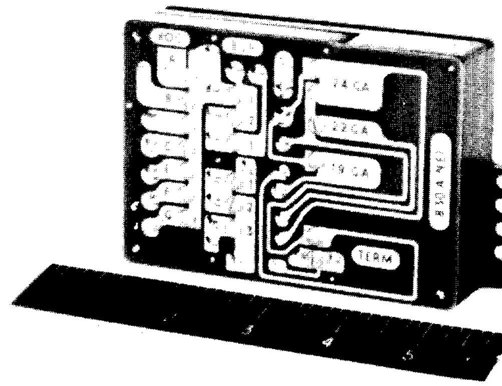


Fig. II-4

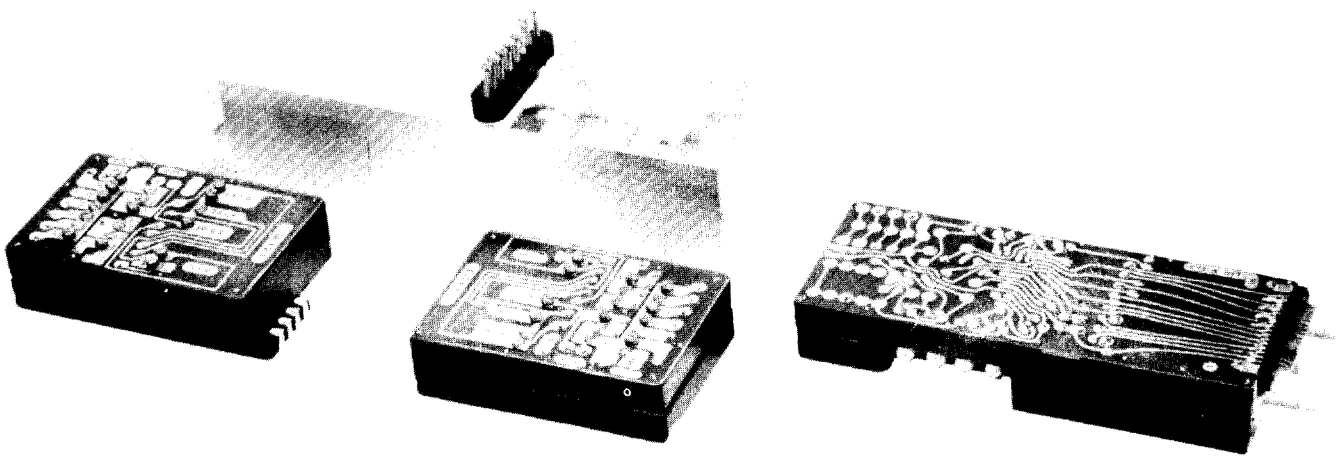


Fig. II-5

2.10 Since the top row of repeaters and those directly below the power-distribution panel are uncovered and the adjusting screws exposed, shields of bay width are furnished with factory-wired bays and units. For bays only partially equipped with shelves, the shields must be ordered separately: P-43D708 for 23-inch bays, and P-43D709 for 19-inch bays. These shields are not shown in the photographs.

2.11 The repeaters are wired between the outside facilities and the office equipment as terminal repeaters, or directly between facilities as intermediate repeaters. It is important that there be no relay equipment (except the disabler) or repeating coil between the repeater and facilities. No impedance compensators are required at points equipped with E6 repeaters. The LBO network takes over the functions of an impedance comensator.

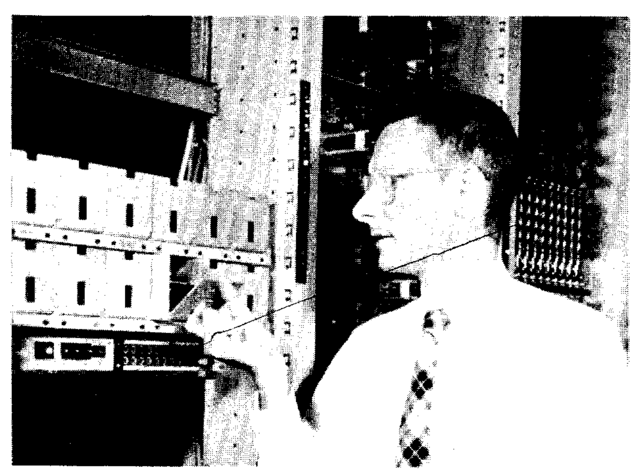


Fig. II-6

3. Operating Limits

3.01 The maximum direct current the line winding of the E6 repeaters can carry is 60 ma.

3.02 The maximum operating temperature is 140°F for the repeater. The transistors may be damaged if operated above this temperature.

4. Test Equipment

4.01 Three items of test equipment have been developed for the E6 system. These are the 54A transmission measuring set, the 54B test stand, and the 54C return loss measuring set. Chapter V describes the 54A and 54B sets. The 54A and 54B sets with a repeater under adjustment are shown in Fig. II-7.

4.02 The 54A and 54C test sets are powered from a jack provided in the 48-volt distribution panel of the repeater bay or equipment unit. The 54C set is also plugged into a 120-volt 60-cycle outlet.

4.03 The 54A transmission measuring set is used to make gain-unit and separate converter-element gain measurements and to make overload checks to detect possible transistor deterioration. These measurements are made with the gain unit between 900-ohm terminations in the test set, with no connection to the line. The set contains a 1000-cps oscillator, a detector, a variable attenuator, and an expanded-scale output meter. Gain measurements are made at 1000 cps only.

4.04 For LBO and gain-unit adjustments, plug the repeater into the 54B test stand. This makes all adjusting screws easily accessible. The 54B test stand includes a line-connector cord which plugs into the repeater bay 48-volt socket, an inductor for holding dialed-up terminations, and a switch and jacks to facilitate various test connections.

4.05 The LBO network adjustments are made with the repeater in the 54B test stand and by the use of the 54C return-loss measuring set. (See Chapter V, Appendix A for methods of doing this without the 54C set.) This set permits the LBO networks to be adjusted to provide maximum return loss against a 900-ohm plus 2-mf termination with the LBO network connected to the actual cable pair.

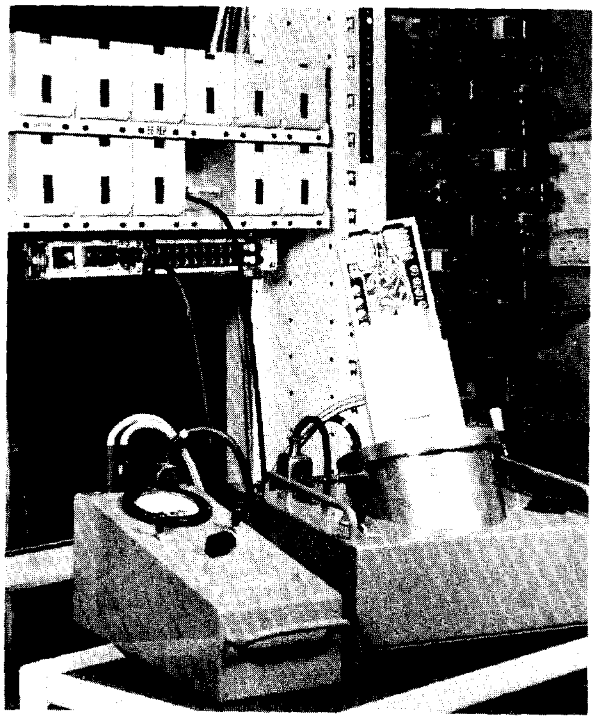
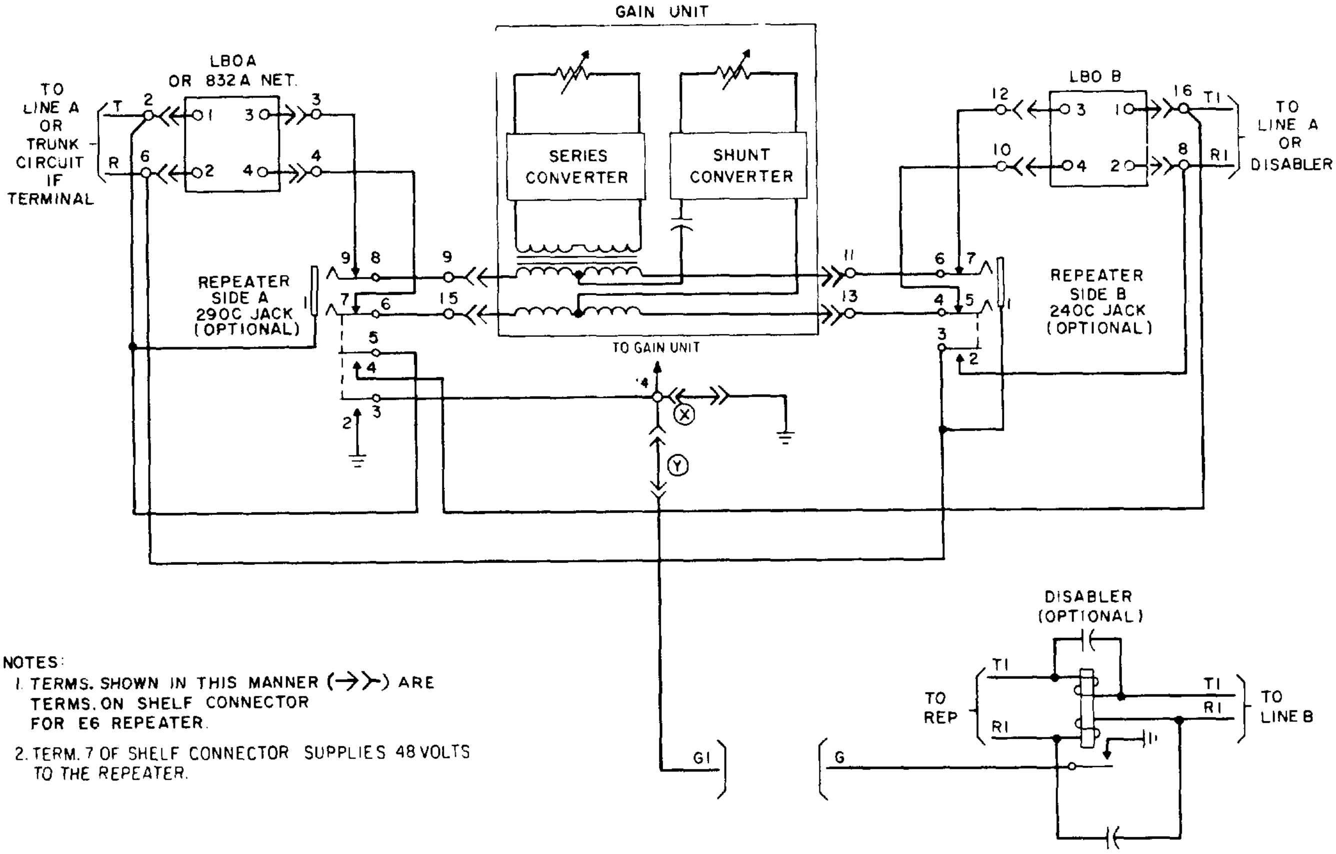


Fig. II-7

5. Test Jacks

5.01 Test jacks are optional in shop-wired bays or on 2-shelf assemblies. These jacks are located at chest height in full bay layouts. They provide access to the repeaters, but not to the line facilities. However, they do cut the line facilities through, around the repeater, as long as plugs remain in the jacks. They also provide a convenient place for monitoring. A schematic of the repeater with test jacks and disabler (also optional) is shown in Fig. II-8.

5.02 With test jacks a routine maintenance test on the repeater can be made quickly with a 54A set alone. There is no need to remove the trunk from service. Without test jacks the repeater must be removed from the shelf and



LINE CONNECTION SCHEMATIC

Fig. II-8

inserted in a 54B test stand for routine gain and overload checks.

5.03 A 491B disabling plug inserted in the TST 1 and TST 2 jacks at the front of the repeater temporarily disables the repeater (eliminating the gain) while the line terminals are cut through. Insertion of this plug reduces repeater gain to 0 db, so that the repeater will not sing, regardless of line changes. This plug should be used only as a temporary means for removing gain from a trunk. (The plug protrudes from the front plane of the repeater into the aisle space.)

CHAPTER III

APPLICATION

1. General

1.01 This chapter presents information on the electrical characteristics and performance of E6 repeaters.

2. Complete Repeater

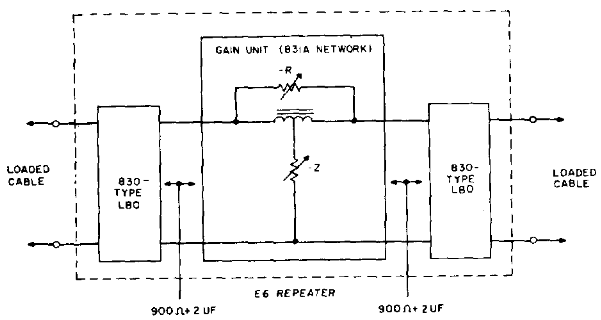
2.01 The repeater consists of three parts: a gain unit (the 831A network) and two line building-out (LBO) networks (830 type). For terminal repeater applications, one 830 network is replaced by a dummy network (832A) which connects the shelf jacks directly to one side of the gain unit. These arrangements are shown schematically in Fig. III-1 and III-2.

2.02 The LBO networks transform the variable (with frequency) impedance of loaded cable pairs to a constant impedance of 900 ohms in series with 2 mf. The gain unit always operates into this impedance. The LBO network is much like an impedance compensator except that it can accommodate endsections from 0 to 5800 feet total. This total, however, must include the capacitance and resistance of inside cable and frame wiring.

3. Gain Unit

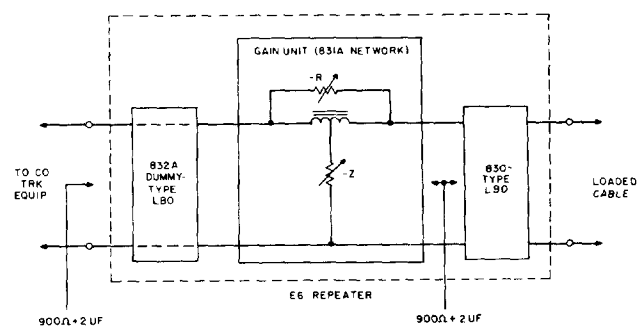
3.01 The gain unit, or 831A network is a transistorized series-negative-impedance converter connected in a bridged-T configuration with a similar shunt converter. The negative impedance of each converter is varied by changing only resistances in its network. By coordinating the adjustment of the series network and the shunt network, the gain can be varied, in steps of 0.1 db or less, from 1 to 13 db, and at the same time the image impedance of the gain unit is kept very close to the desired 900 ohms and 2 mf.

3.02 The network adjustment for the series converter consists of nine screws labeled A to J. Each screw shorts out one resistor of a string of resistors connected in series. Each resistor has approximately twice as much resistance as the preceding one. This system



INTERMEDIATE E6 REPEATER

Fig. III-1



TERMINAL E6 REPEATER

Fig. III-2

minimizes the number of resistors and screws needed for the fine adjustments provided. The screw settings of the network are always designated as those screws turned down; in this case, those screws which short-out resistors. The total resistance in the network is, therefore, the sum of the resistor values for those with raised screws. (See Fig. III-3.)

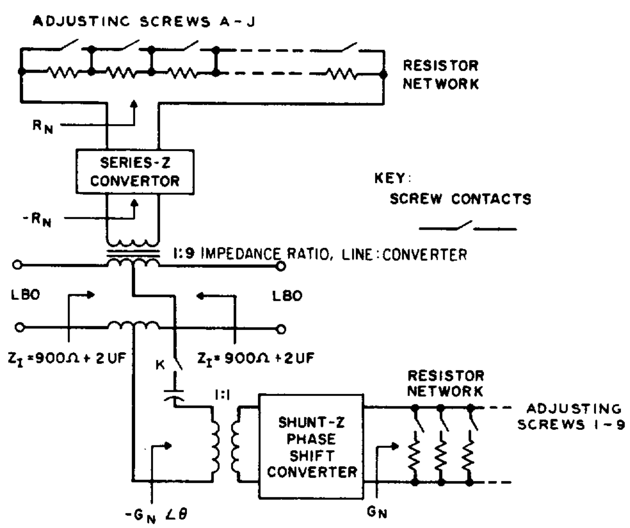


Fig. III-3

3.03 The adjusting screws have captive washers directly under the heads, which provide contact with the surface bus-bar wiring on the printed-wiring terminal boards. There are no internal hidden contacts. The screws move in nylon nuts; the nylon prevents shifting or loosening. Usually, three complete turns are sufficient to raise the washer clear of the wiring and to fully open the contact. Screws that are to be tightened should be tightened moderately. Excessive tightening may strip the threads.

3.04 The shunt converter is similarly adjusted by screws numbered 1 to 9, but in this case the network resistors are connected in parallel and tightening a screw adds the conductance of the corresponding resistor to the conductance of all others with tightened screws.

3.05 The adjustments of the series and shunt converter screws to provide gains from 1 to 13 db are listed in Table A (attached), together with the resistance and conductance values. Even finer gain steps than 0.1 db can be obtained by interpolating between the listed steps. A similar table, but without the resistance and conductance sums, is given in Chapter VI, Putting in Service. A copy of the same table encased in plastic is part of each 54B test stand.

3.06 When the repeater is used on trunks where the last fractional db of repeater gain is not sought, these tabulated adjustments will be sufficient. However, where it is desired to operate the repeater at the maximum gain that the line will permit, it may be necessary to vary the adjustments slightly on individual 831A networks. Such action is necessary only in case of an adverse combination of tolerances of the repeater components. This latter occurs rarely. The 54A transmission measuring set permits exact adjustment of the series and shunt converter networks so that the gain unit has the desired image impedance. This set also permits measuring the total gain of the gain unit.

3.07 The series converter is connected to the line through a 9:1 line transformer. The shunt converter is connected through a 1:1 transformer in series with a capacitor that blocks the dc path.

3.08 The load-handling capacity of the gain unit depends on the gain and impedance to which it is adjusted. For an impedance of 900 ohms in series with 2 mf, it varies from an output level of +22 dbm with 2-db gain to +16 dbm with 12-db gain. Because of the push-pull arrangement of the circuit, overloading appears as a compression in the output-versus-input characteristic rather than clipping of the speech signal. Because of the large amount of feedback and the push-pull arrangement, certain transistor impairments may not be measurable or noticeable on weak or average speech volumes, but may be apparent on speech peaks or for loud-volume talkers. The 54A set is, therefore, arranged to make a high-level test close to the overload point of the gain unit. This value depends on the particular gain setting, and the 54A set gain switch automatically determines the proper level to be applied.

4. LBO Networks

4.01 These are passive element networks similar in function to impedance compensators. They have the following adjustments:

(1) Building-out resistance (BOR) 0 to 196 ohms in 28-ohm steps.

(2) Building-out capacitance (BOC) 0 to 0.101 mf in 0.001-mf steps.

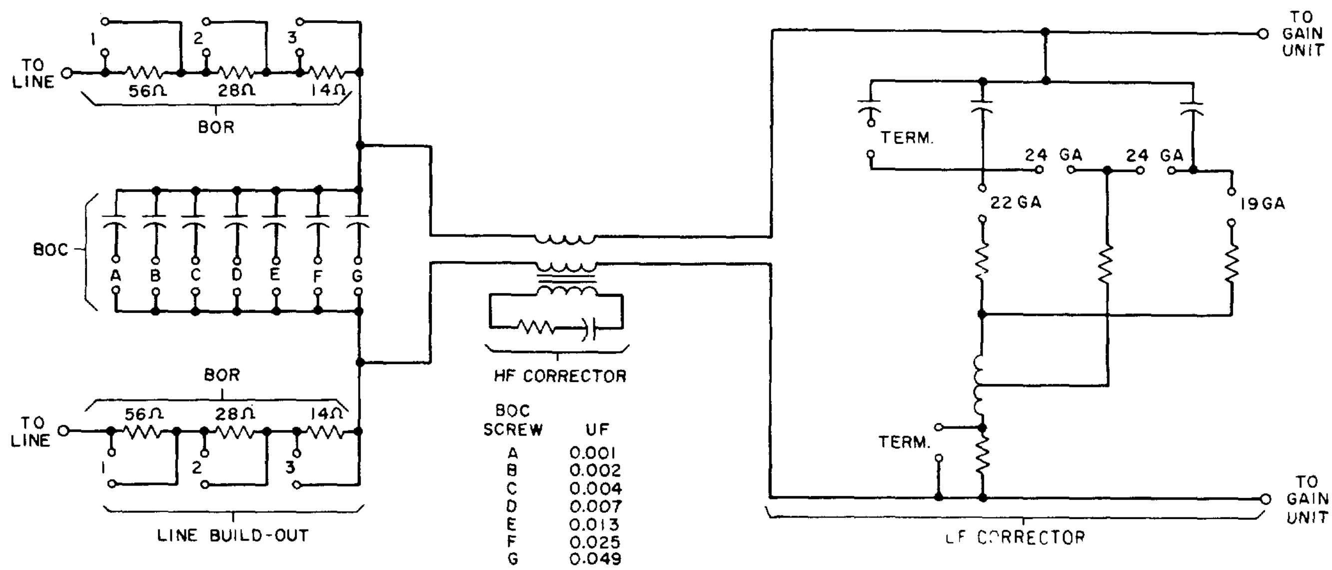
(3) A low-frequency corrector network (LFC) suitable for terminal or intermediate repeaters on 19-, 22-, or 24-gauge cable pairs.

Fixed elements in the LBO network are determined by the cutoff frequency and impedance characteristics of the loaded cable. These latter are determined by the type of loading and the mutual capacitance of the cable pairs. A schematic of the LBO network is shown in Fig. III-4.

should be used. The return loss degradation cannot be estimated; it depends on how precisely the layout is known and on deviations from nominal cable characteristics.

5. What the E6 Repeater Will Not Do

5.01 While the E6 repeater can compensate to a limited extent for mixed-gauge pairs in the endsection and for high-capacitance office cabling which is in tandem with the outside cable, it cannot compensate for irregularities in the cable pairs beyond the first loading coil. Such irregularities cause poor structural return loss. However, when an E6 repeater is installed at the junction between two cable pairs of different gauge or different mutual capacitance, the LBO networks can be varied to remove the effect of this type irregularity.



830A LINE BUILDING-OUT NETWORK

Fig. III-4

4.02 The adjustable features incorporated in the LBO network and the accuracy of adjustment of the image impedance of the gain unit permit E6 repeaters to operate at higher gains than E23 repeaters. In general, little improvement will be obtained on cables with structural return loss below 20 db. However, on cables with high structural return loss, considerable improvement will be obtained.

4.03 Where LBO adjustments are to be prescribed in advance from cable layouts and the LBO's are not adjusted by test, the maximum permissible gain chart for E23 repeaters

6. Definition of Repeater Gains

6.01 Because of the presence of the LBO networks and the insertion loss that these networks introduce, the concept of repeater gain is somewhat different from that for E23-type repeaters. The loss of the LBO network is included with the line loss. The inserted gain is that of the gain unit itself operating into 900-ohm plus 2-mf impedances. The loss of the LBO network varies with the amount of BOR used and to a smaller extent with the length of end-section. The amount of loss which is introduced by the LBO network is of no consequence in determining the final circuit net loss. While it is true that the loss of the LBO network increases with the amount of BOR used, the return loss presented to the repeater increases at a much faster rate. This increase in return loss permits increasing the gain of the repeater to more than overcome the increased loss due to the BOR. The gain unit has sufficient gain range and sufficient load-handling capacity to overcome the LBO loss.

7. Definition of Terms

7.01 Gain-unit gain is the insertion gain of the converter unit between a 900-ohm generator and a 900-ohm load at 1000 cps. This is the value measured by the 54A test set.

7.02 LBO loss is the 1000-cps insertion loss of the LBO network between the line of a given endsection and 900-ohms. LBO loss is given as a constant plus the loss of cable necessary to build the endsection out to 5800 feet.

7.03 Repeater gain is the power gain of the complete repeater including gain unit and LBO networks at 1000 cps. For engineering calculations it is equal to the gain-unit gain minus the LBO losses as defined above. In view of this definition of gain, no reflection loss at an E6 location should be included in net line loss calculations.

7.04 Converter element gain is the insertion gain of either the series or the shunt-converter element in a 900-ohm circuit. The major function of measuring this gain is to compare the series and shunt elements as a check on structural return loss adjustment of the gain unit.

7.05 Repeater structural return loss is the return loss of the repeater itself measured at the gain-unit terminals against 900-ohms in series with 2 mf, plus twice the gain-unit gain. It can be an echo, critical frequency, or single-frequency value. For example, if the echo structural return loss of a repeater is given as 32 db minimum, the measured return loss at the gain-unit terminals when this is adjusted for 7 db gain is 32 db minus 2 times 7 db, which equals 18 db minimum measured value.

8. Longitudinal Balance

8.01 The longitudinal balance of the E6 repeater is adequate, permitting high longitudinal voltages on the pair without causing overloading effects within the repeater and without increasing the noise except as the repeater amplifies the voice band. The limits for induced longitudinal voltages are 45 volts rms open-circuit at 60 cps and 20 volts rms, open-circuit at 180 cps.

9. Operating Limits

9.01 The maximum direct current the line windings of the E6 repeater can carry is 60 ma.

9.02 The maximum operating temperature is 140°F at the repeater location. The transistors may be damaged if operated above this temperature. The repeaters, therefore, should not be installed directly above equipment which operates at high temperatures.

10. Signaling Penalties

10.01 The signaling penalties for the E6 repeater are similar to those for the E23 and are given in Chapter IX. Dc resistance of the E6 repeater is 40 ohms for the 831A network plus 25 ohms for each 830 network. In addition, the LBO networks build out the resistance of the endsection. This adds 0 or 28 ohms for LBO on 19-gauge pairs; up to 84 ohms on 22-gauge pairs with a typical value of 28 ohms; and up to 196 ohms on 24-gauge pairs, but typically 56 ohms. The total resistance inserted by the E6 repeater may exceed the limits for certain signaling arrangements. Therefore, in cases where signaling is critical, but transmission is not, it is possible to omit all or part of the BOR adjustment. The optional repeater disabler, which can be used instead of idle-circuit terminations, to increase the permissible-gain setting, adds another 120 ohms to the loop resistance.

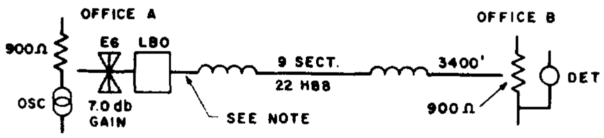
11. Repeater Performance

11.01 Repeater performances on laboratory and actual trunks are shown in Fig. III-5 through -10. The values shown are for repeaters and trunks adjusted to be stable with all combinations of passive networks at trunk terminals. Values in Fig. III-5 through -8 were obtained on cables with high structural return loss.

11.02 Examination of the curves and data indicate that net losses suitable for toll-connecting or tandem trunks are being achieved, except for the intermediate 24-gauge case. The effect of the mismatch due to the far-end termination, which in this case was a compromise network, can be observed. There is a marked improvement in return loss when the far end of the line is terminated in a precision network, as shown in the data. In actual use, of course, the far end will be switched to a wide variety of subscriber loops, many of which will have lower return loss than that shown by the compromise network.

11.03 Fig. III-9 and 10 show the comparative performance of trunks between Essex Tandem and Plainfield, New Jersey, first equipped with intermediate E23 and then with E6 repeaters. The net-loss-versus-frequency measurements which are shown in Fig. 9 give an effective loss for the E23-equipped trunks of 7.2 db, while the effective loss of the E6-equipped trunks is 5.5 db. The corresponding return losses measured at Essex Tandem through an impedance compensator are shown in Fig. 10. These indicate 2- to 4-db improvement in echo return loss for the E6-equipped circuit, even though this circuit is operating at 1.7-db lower net loss.

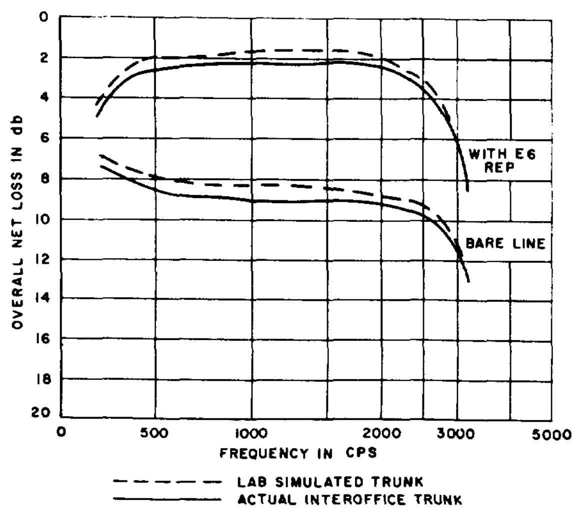
PERFORMANCE OF E6 REPEATER TERMINAL ON 9 LS OF 22 H88 FRAME TO FRAME



MEASURED NET LOSS

	1000~ WITHOUT REP	1000~ WITH REP	EFFECTIVE WITHOUT REP	EFFECTIVE WITH REP
LAB SETUP	8.3 db	1.7 db	8.6 db	2.3 db
ACTUAL	9.0 db	2.3 db	9.2 db	2.9 db

RESPONSE VS FREQUENCY



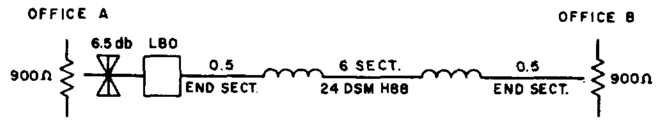
RETURN LOSS AT OFFICE A WITH COMP NET TERM. AT OFFICE B

	500 - 2500 ~	2000 - 3000 ~	MIN	CABLE STRUCTURAL RETURN LOSS
ACTUAL	20.3 db	14.4 db	8.3 db @ 2900~	38.1 db
LAB SETUP	20.6 db	19.0 db	17.0 db @ 2900~	>40.0 db

NOTE: RECORD CARD SHOWS 3075 FT BUT BOC ADJUSTMENT INDICATED 3500 FT EQUIVALENT. BOC = 0.036 UF, BOR = 28Ω

Fig. III-5

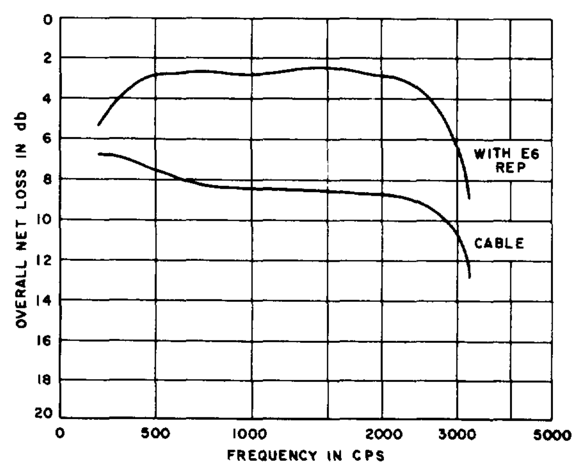
PERFORMANCE OF E6 REPEATER TERMINAL ON 6 LS OF 24 H88 FRAME TO FRAME



MEASURED NET LOSS

1000 ~ WITHOUT REP	1000 ~ WITH REP	EFFECTIVE WITHOUT REP	EFFECTIVE WITH REP
8.5 db	2.8 db	8.5 db	3.2 db

RESPONSE VS FREQUENCY



RETURN LOSS AT OFFICE A WITH COMP NET TERM. AT OFFICE B

500 - 2500 ~	2000 - 3000 ~	MIN
20.7 db	19.4 db	15.0 db @ 400 ~ 16.2 db @ 2400~

WITH PREC NET AT OFFICE B

500 - 2500 ~	2000 - 3000 ~
24.0 db	26.0 db

Fig. III-6

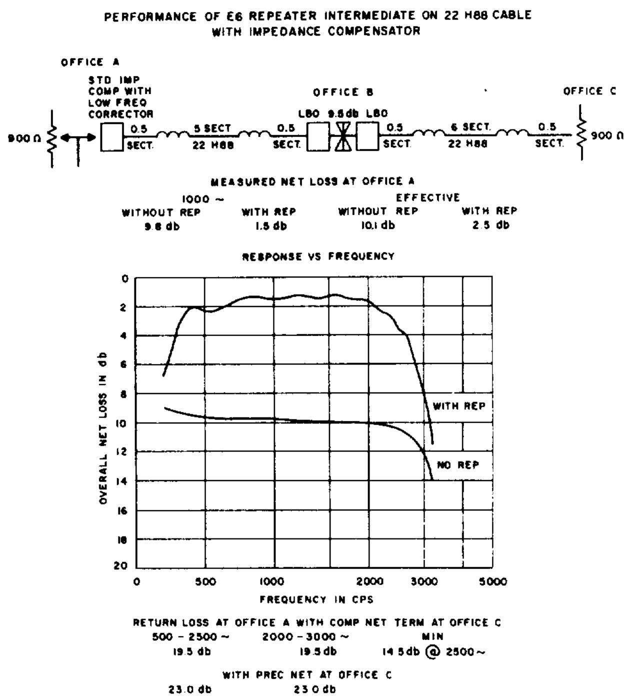


Fig. III-7

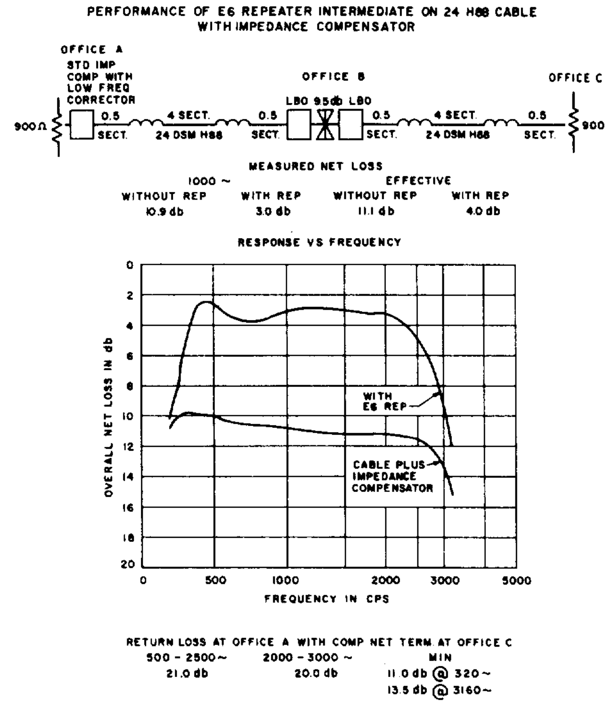


Fig. III-8

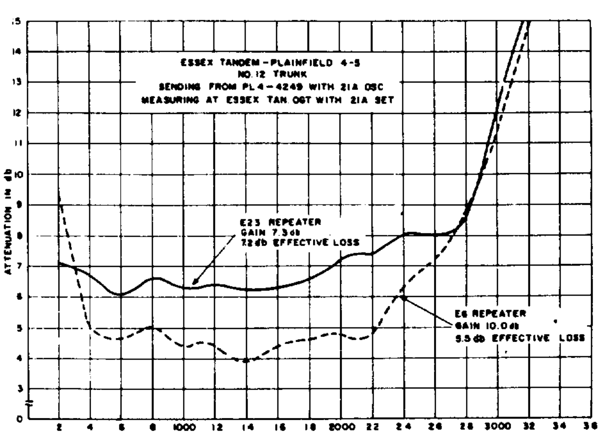
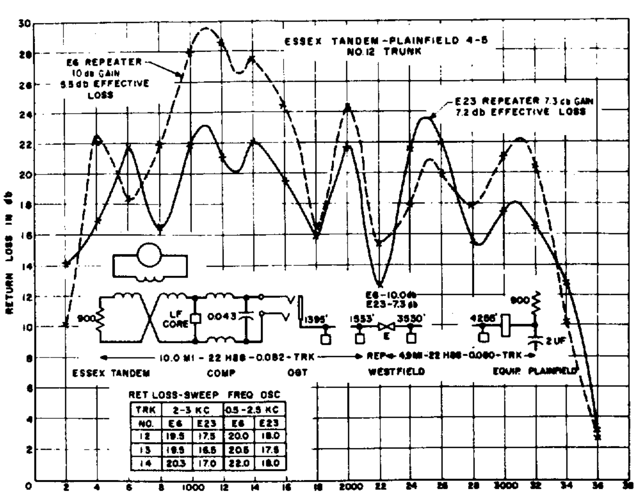


Fig. III-9



TRK	2-3 KC		0.5-2.5 KC	
NO.	E6	E23	E6	E23
12	19.5	17.5	20.0	18.0
13	19.5	16.5	20.5	17.5
14	20.3	17.0	22.0	18.0

Fig. III-10

12. Structural Return Loss of the Repeater

12.01 Fig. III-11, -12, -13, and -14 show the structural return loss of an adjusted LBO and gain unit measured at the terminals of the gain unit. This return loss is measured against an impedance of 900 ohms in series with 2.16 mf. For the terminal repeater cases, it shows that the repeater provides an impedance match superior to the impedance compensator. These return losses are structural return losses which can be combined with cable structural return losses on a power-addition basis. The power sum is then referred to the repeater terminals by subtracting twice the gain-unit gain. Fig. III-11 also shows the impairments in return loss when the BOR adjustments are not used. The poorer return loss for endsections having capacitance greater than that of 5800 feet of outside cable is shown in Fig. III-13.

12.02 Fig. III-12 and -14 are similar structural return loss curves for the LBO adjustment for intermediate repeaters. A different LBO adjustment is used for intermediate repeaters in order to improve signaling margins by raising the LFC network bridged impedance. There is little impairment in return loss for a 19-gauge LFC, but from 8 to 10 db for 22- and 24-gauge LFC adjustments. Again the effect of long endsections on return loss is apparent.

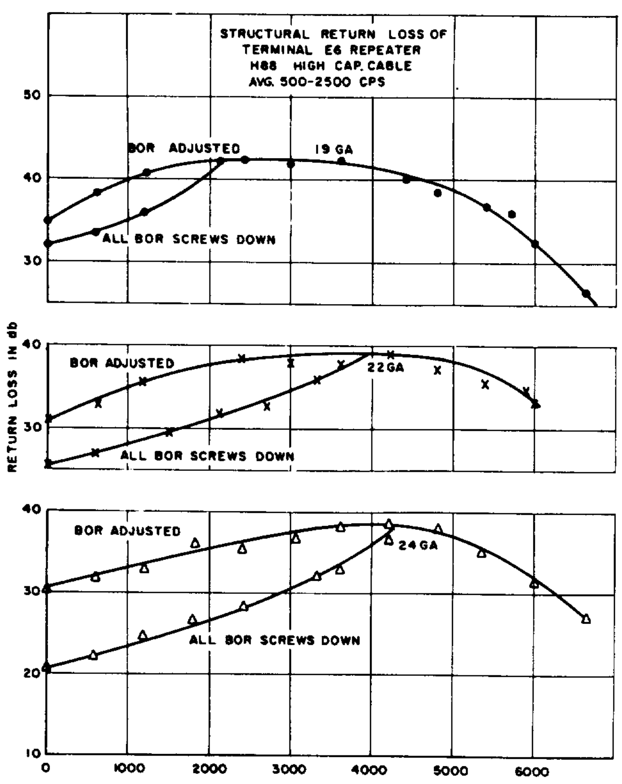


Fig. III-11

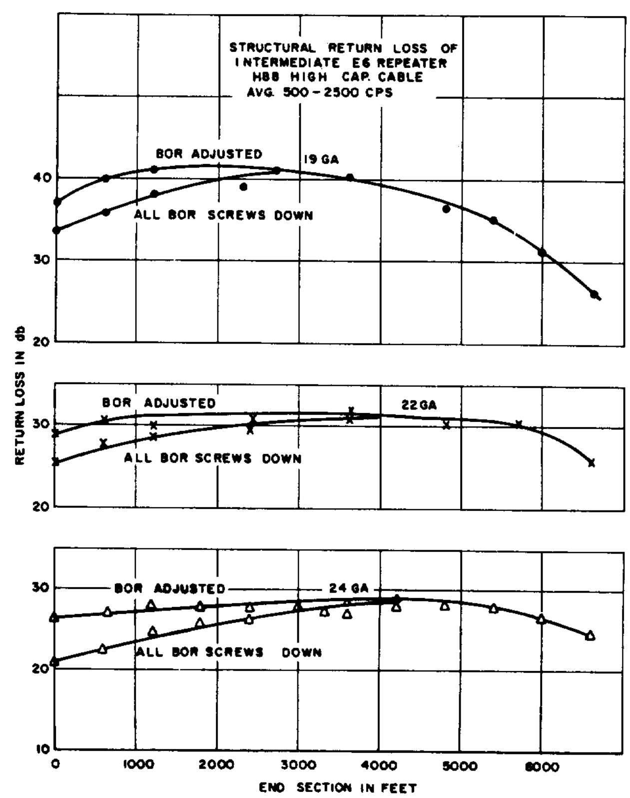


Fig. III-12

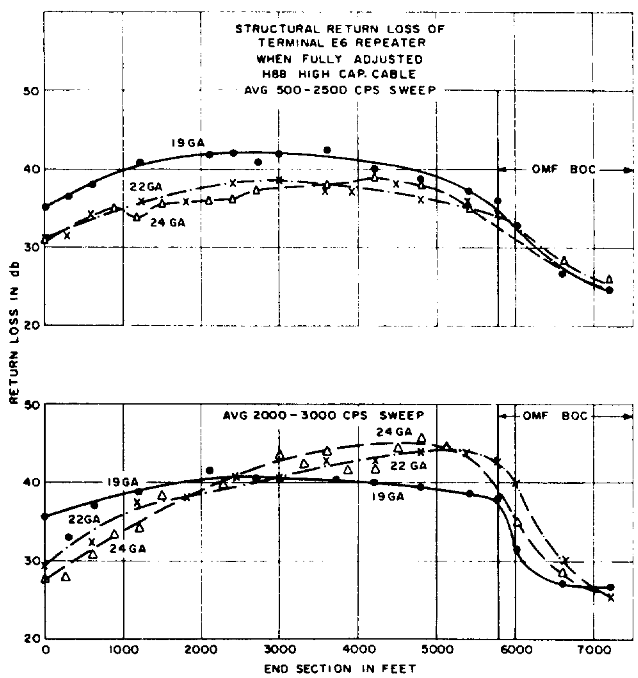


Fig. III-13

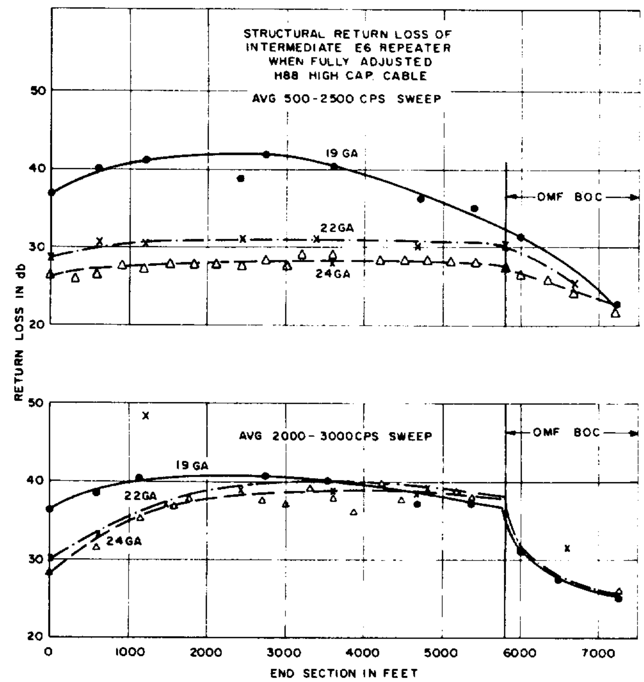


Fig. III-14

13. Return Loss of a Terminal Repeater at the Line Terminals

13.01 In some cases, especially when an E6 repeater is located at the class-5 end of a terminating link, the return loss between the cable pair and LBO-plus-gain-unit is of interest. These data are shown in Fig. III-15, 16, and 17. Echo return loss (500 to 2500 cps) for all three gauges is excellent. Return losses at 3000 cps average about 8 db, which is better than that attributed to subscriber loops: an average of 6 db with a standard deviation of 2 db.

13.02 Any return loss caused by a terminal impedance different from 900 ohms in series with 2.16 mf has, of course, to be added to the repeater return loss by referring it back to the desired point in the circuit.

14. Functions of Test Sets

14.01 Three test sets developed for use with the E6 repeater are described in Chapter V. These sets serve both for initial adjustments and for routine maintenance checks. The 54C return loss measuring set also has general purpose applications for adjustments of impedance compensators, for measurements of echo return loss, for cable acceptance tests, and for cable irregularity location.

14.02 The 54A transmission measuring set serves both for initial check and adjustment of the gain unit and for routine checks of the gain and overload performance of the gain unit after installation. Until experience has been acquired with the E6 repeater, the intervals between such routine checks are purely arbitrary. Only time and exposure of the repeaters will indicate what these intervals should be. Initially a period of about a year is suggested.

14.03 The 54B test stand holds the repeater so that the adjusting screws are accessible. It furnishes connections from the shelf connector (lines A and B) to the repeater, it powers the repeater, and it makes connections to the test sets.

14.04 The 54C return loss measuring set measures the effects of BOR, BOC, and LFC screw adjustments of the LBO networks. Much of the improved performance of the repeater depends on the optimum adjustment of these networks. Experience in several field installations indicates that the cable records are not precise indicators of the endsection capacitance and resistance. The records almost always appear to understate the capacitance of the endsection by amounts that range from several hundred to fifteen hundred feet in length. Actual measurement with the 54C set compensates for the true endsection capacitance and makes it possible to compensate to a large extent for mixed gauges and deviations in cable characteristics in the endsection.

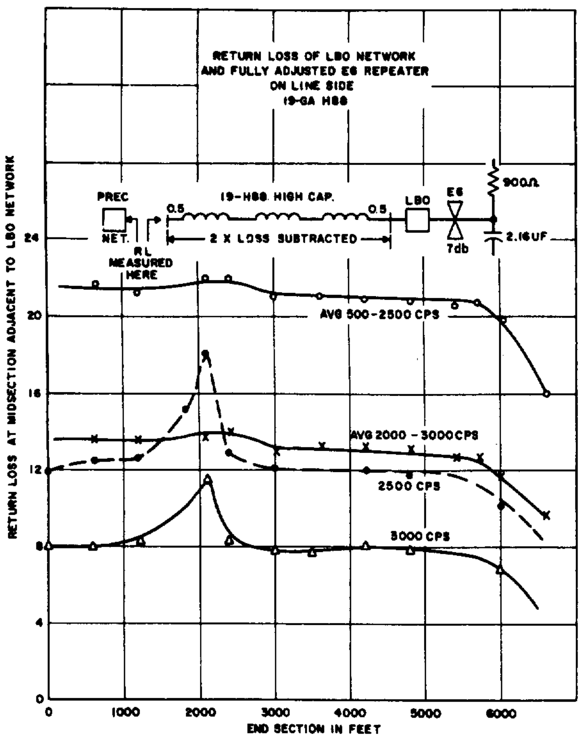


Fig. III-15

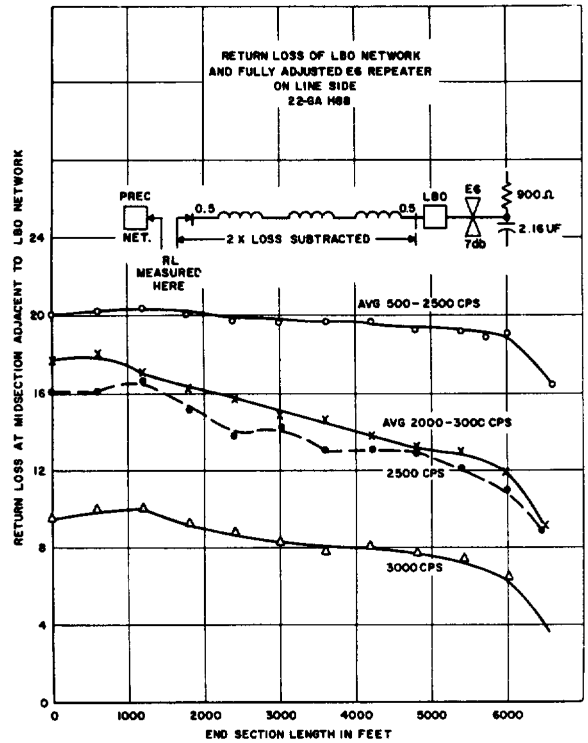


Fig. III-16

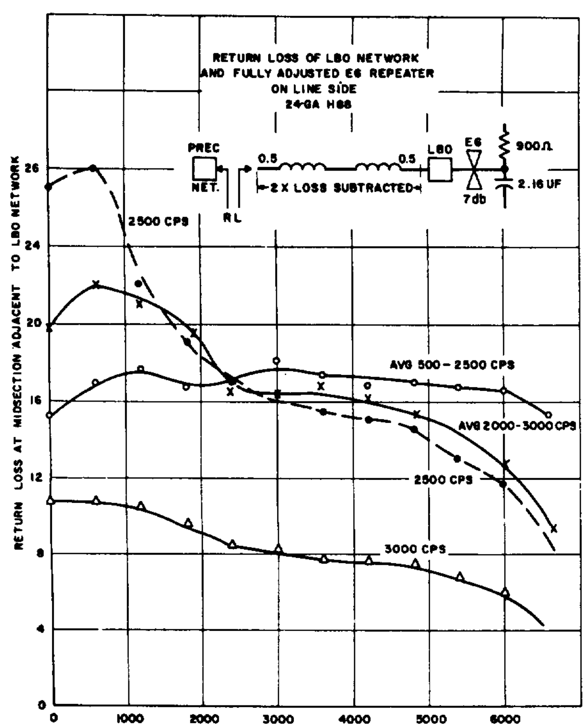


Fig. III-17

TABLE A

831A NETWORK ADJUSTMENTS
FOR 900-OHM IMAGE IMPEDANCE

PRELIMINARY

Total Gain	Series or Shunt Converter Gain	Series Screws Down	Total Series Network Resistance	Shunt Screws Down	Total Shunt Network Conductance
db	db		ohms		umhos
1.0	0.5	ADEFHJ	2,790	36	175
1.1	0.6	CEFHJ	2,990	146	200
1.3	0.7	ABCDFHJ	3,184	12346	229
1.5	0.8	BDFHJ	3,384	356	254
1.7	0.9	ACFHJ	3,584	1456	279
1.9	1.0	FHJ	3,784	123456	308
2.1	1.1	ABDEHJ	3,980	137	337
2.2	1.2	BCEHJ	4,180	1247	366
2.4	1.3	BEHJ	4,340	157	396
2.6	1.4	ACDHJ	4,534	2357	421
2.8	1.5	DHJ	4,734	12457	445
3.0	1.6	CHJ	4,894	167	473
3.1	1.7	ABCDEFGJ	5,110	2367	498
3.3	1.8	ABDEFGJ	5,270	12467	522
3.4	1.9	ABCEFGJ	5,430	567	547
3.6	2.0	BEFGJ	5,630	13567	572
3.8	2.1	ACDFGJ	5,824	124567	601
4.0	2.2	ADFGJ	5,984	8	625
4.1	2.3	ACFGJ	6,144	138	650
4.3	2.4	FGJ	6,344	148	669
4.4	2.5	CDEGJ	6,500	2348	694
4.6	2.6	DEGJ	6,660	1258	719
4.8	2.7	ABEGJ	6,860	12358	738
4.9	2.8	ABCDGJ	7,014	3458	763
5.1	2.9	BDGJ	7,214	168	786
5.3	3.0	BCGJ	7,374	2368	810
5.4	3.1	BGJ	7,534	2468	830
5.6	3.2	BCDEFJ	7,700	123468	854
5.7	3.3	BDEFJ	7,860	12568	874
5.8	3.4	ACEFJ	8,060	4568	899
6.0	3.5	AEFJ	8,220	34568	918
6.1	3.6	ACDFJ	8,374	178	942
6.3	3.7	ADFJ	8,534	1378	962
6.5	3.8	ACFJ	8,694	1478	982
6.6	3.9	AFJ	8,854	23478	1,006

(Cont'd)

TABLE A (CONT'D)

- 2 -

PRELIMINARY

Total Gain	Series or Shunt Converter Gain	Series Screws Down	Total Series Network Resistance	Shunt Screws Down	Total Shunt Network Conductance
db	db		ohms		umhos
6.7	4.0	CDEJ	9,050	2578	1,026
6.9	4.1	DEJ	9,210	23578	1,046
7.0	4.2	CEJ	9,370	24578	1,065
7.2	4.3	EJ	9,530	234578	1,085
7.3	4.4	CDJ	9,684	12678	1,108
7.5	4.5	DJ	9,844	23678	1,123
7.6	4.6	CJ	10,004	24678	1,142
7.7	4.7	J	10,164	234678	1,162
7.9	4.8	CDEFGH	10,320	25678	1,182
8.0	4.9	ADEFGH	10,440	135678	1,197
8.1	5.0	ACEFGH	10,600	145678	1,216
8.2	5.1	AEFGH	10,760	1345678	1,236
8.4	5.2	ACDFGH	10,914	9	1,256
8.6	5.3	ADFGH	11,074	129	1,271
8.7	5.4	BCFGH	11,194	1239	1,291
8.8	5.5	BFGH	11,354	249	1,305
9.0	5.6	ABCDEGH	11,470	2349	1,325
9.1	5.7	ABDEGH	11,630	159	1,340
9.2	5.8	ABCEGH	11,790	1359	1,360
9.4	5.9	CEGH	11,910	1459	1,379
9.5	6.0	AEGH	12,030	3459	1,394
9.6	6.1	ACDGH	12,184	69	1,412
9.8	6.2	BDGH	12,304	369	1,432
9.9	6.3	BCGH	12,464	12369	1,446
10.0	6.4	ABGH	12,584	12469	1,466
10.2	6.5	ABCDEFH	12,750	23469	1,481
10.3	6.6	CDEFH	12,870	1569	1,496
10.4	6.7	ADEFH	12,990	13569	1,515
10.6	6.8	BCEFH	13,110	4569	1,530
10.7	6.9	BEFH	13,270	124569	1,545
10.8	7.0	ABCDFH	13,384	1234569	1,564
11.0	7.1	CDFH	13,504	279	1,579
11.1	7.2	ADFH	13,624	1379	1,593
11.2	7.3	BCFH	13,744	479	1,608
11.3	7.4	ABFH	13,864	12479	1,623

(Cont'd)

TABLE A (CONT'D)

- 3 -

PRELIMINARY

Total Gain	Series or Shunt Converter Gain	Series Screws Down	Total Series Network Resistance	Shunt Screws Down	Total Shunt Network Conductance
db	db		ohms		umhos
11.5	7.5	FH	13,984	123479	1,642
11.6	7.6	ACDEH	14,100	2579	1,657
11.7	7.7	BDEH	14,220	13579	1,672
11.8	7.8	ABCEH	14,340	4579	1,687
12.0	7.9	ABEH	14,500	124579	1,702
12.1	8.0	AEH	14,580	234579	1,716
12.2	8.1	BCDH	14,694	1679	1,730
12.3	8.2	ABDH	14,814	3679	1,744
12.5	8.3	DH	14,934	123679	1,759
12.6	8.4	ACH	15,054	24679	1,774
12.7	8.5	BH	15,174	234679	1,793
12.8	8.6	H	15,254	15679	1,808
13.0	8.7	ACDEFG	15,390	35679	1,823
13.1	8.8	BDEFG	15,510	1235679	1,838
13.2	8.9	ABCEFG	15,630	245679	1,852
13.3	9.0	CEFG	15,750	1345679	1,867

CHAPTER IV

CIRCUIT LAYOUT

1. GENERAL

1.01 This chapter discusses the various factors that should be considered in the design of circuits using the E6 repeater. Methods and data are presented to enable the circuit layout engineer to determine, for a particular circuit layout, the maximum allowable gain-unit gain (see Fig. IV-1) consistent with system objectives concerning singing, echo, crosstalk, and overloading. In addition, data pertaining to limitations of signaling and supervision imposed by the E6 repeater, as well as by the equipment on the circuit, are included, and methods for using them are described.

1.02 The E6 repeater is applicable to only those facilities for which matching LBO's are available. During the last quarter of 1959, only the 830A type of LBO will be produced, matching H88-loaded high-capacitance 19- through 24-gauge cable pairs to the repeater. Sometime during the first half of 1960, the 830B type of LBO should be ready for shipment. This network will match either H88-loaded low-capacitance 19-gauge cable or D88-loaded high-capacitance 19- or 22-gauge cable to the E6 repeater.

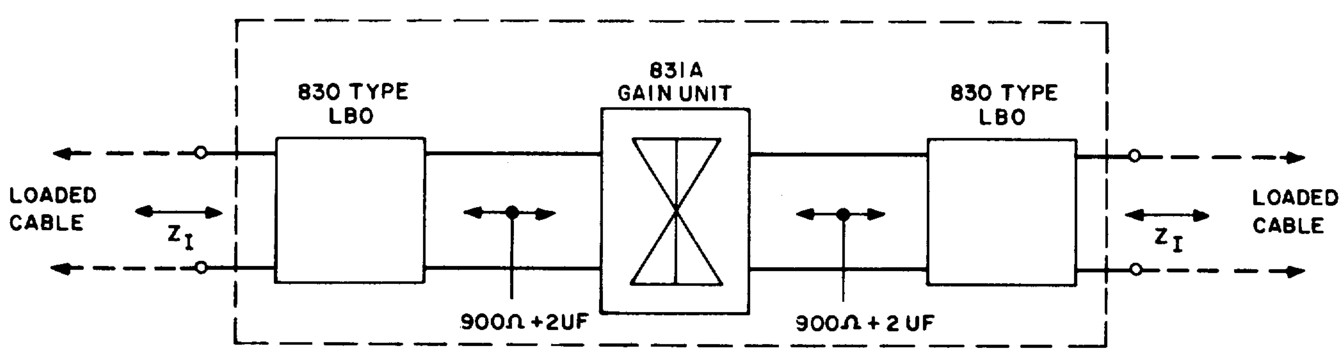
2. APPLICATION PRINCIPLES

Maximum Allowable Gain-Unit Gain

2.01 From the stability standpoint, the maximum allowable gain of the gain unit of the E6 repeater is limited by the degree of departure between the image impedance, Zi, of the gain unit and the impedance presented at the terminals of the gain unit.

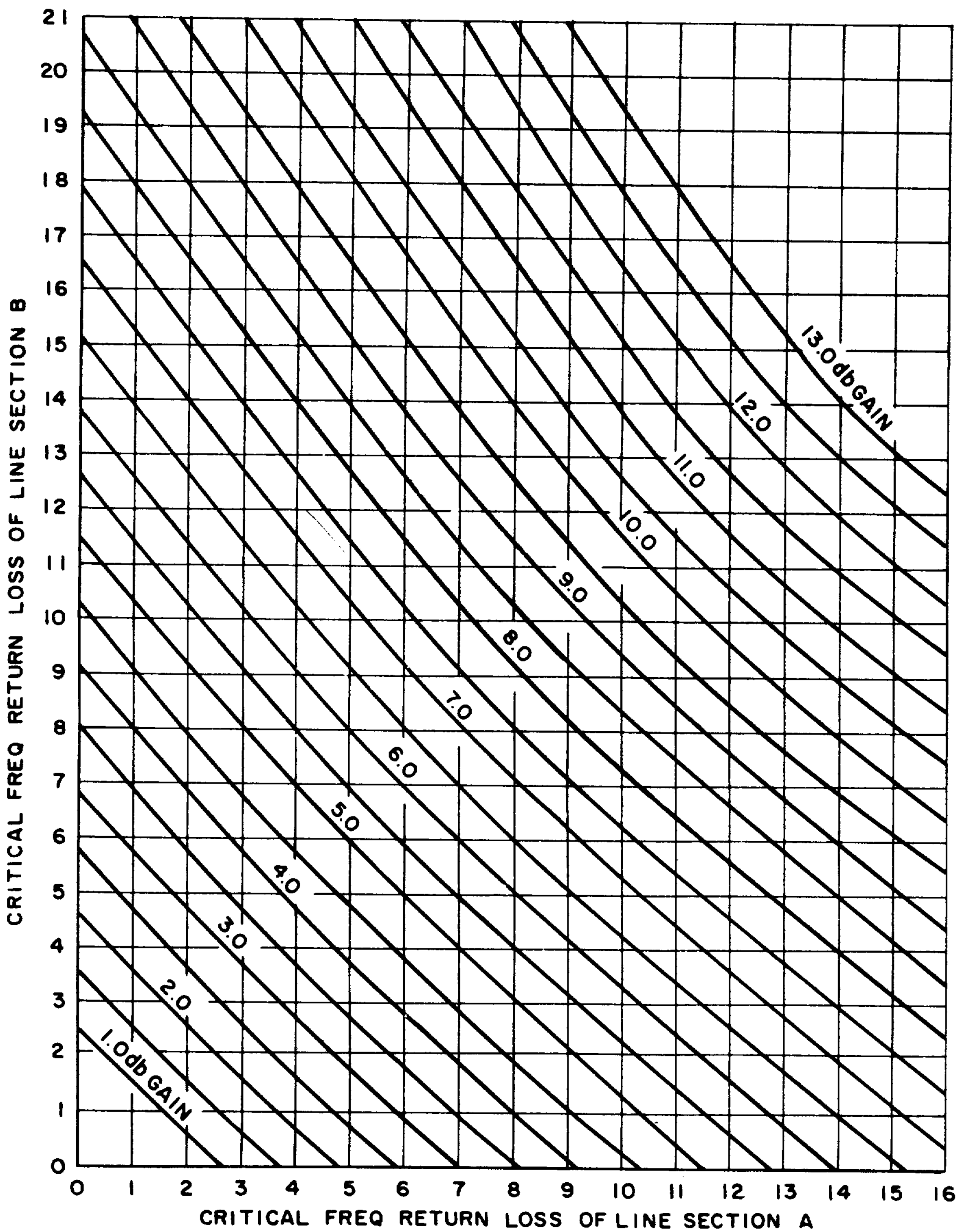
2.02 The impedance seen by the gain unit, on side A and on side B, includes the effect of all the impedance mismatches in the circuit between its terminals and the gain-unit location.

2.03 For engineering purposes in the Bell System, each of these mismatches is expressed in terms of return loss in decibels. The cumulative effect of all of these return losses *at the gain unit* is called the ***line-section*** return loss. A detailed procedure for determining the line-section return loss is given in Appendix A to this chapter. A series of curves showing the maximum allowable gain-unit gain for various combinations of line-section return loss on each side of the gain unit is shown in Fig. IV-2.



IDEAL INTERMEDIATE E6 REPEATER

Fig. IV-1



MAXIMUM USABLE GAIN OF E6 REPEATER
(GAIN-UNIT GAIN)

Fig. IV-2

Signaling and Supervision Considerations

2.04 The range reducing effects of E6 repeaters are discussed and the penalties to be imposed in specific applications are given in Chapter IX.

Crosstalk Considerations

2.05 *Trunks:* The most severe location for repeaters from a crosstalk standpoint is at the end of a trunk where connection is made to subscriber loops, i.e., at the local-office end of tandem trunks and terminal links, or at either end of direct interoffice trunks. If the gains of such terminal repeaters do not exceed the values shown in the table below, a crosstalk index of "GOOD" should be realized. These gain values are based on typical crosstalk couplings in the cable facilities. When crosstalk couplings are not typical, gains should be adjusted accordingly. For more details on crosstalk see the appropriate series of Bell System Practices.

TYPE OF TRUNK FACILITY (Staggered Twist Cable)	GAIN OF GAIN UNIT
H88	7 db
D88	6 db

In the case of nonstaggered twist cable, the coupling distribution is such that "POOR" crosstalk conditions may result even with small gains. For intermediate repeaters, the gains shown in the table may be increased by the amount of the trunk plus LBO loss between the repeater location and the circuit terminal at the subscriber end. It should be noted, however, that crosstalk considerations may not be the controlling factor in the selection of repeater gain.

2.06 *Special Service Lines:* The gain values given in the table in 2.05 assume that a trunk connects to a typical distribution of subscriber loops for which the 1000-cycle loss of the average loop is 5 to 6 db. In the assignment of repeater gains on special service lines, the values given in the table may be decreased or increased by the amount that the 1000-cycle loss to the station terminal is less than or greater than 6 db.

Avoidance of Overloading Effects

2.07 If an E6 repeater is operated at excessively high output levels, the result is a volume-limiting effect on steady tones and some degree of volume compression on speech. This effect is quite different from the high-harmonic production, distortion, and blocking effects typical of nonlimiting amplifiers.

2.08 Overloading of E6 repeaters may be avoided by designing circuits so as to limit their outputs to the following values, in service:

Speech and music:	+8 vu
Single-frequency power :	+16 dbm

Echo Considerations

2.09 The effect of the E6 repeater on echo return loss will vary with the precision of the LBO and gain-unit gain adjustments. If the LBO adjustments are optimized using the 54C test set, and the gains of the series and shunt converters of the gain unit are adjusted to within 0.2 db of each other using the 54A and 54B test sets, the echo structural return loss (ESRL) of the terminal E6 repeater itself will be at least 32 db, as shown in Fig. III-11 and 13, and that of the intermediate repeater at least 26 db as shown in Fig. III-12 and 14.

2.10 The Cable Acceptance Test data should be used when assigning pairs for trunk applications. When available, pairs having an echo structural return loss of 30 db, or higher, should be selected.

2.11 In general, direct interoffice and tandem trunks are not long enough electrically to present echo problems. However, objectionable sidetone may be encountered unless cable pairs having reasonably high echo structural return loss are used and LBO and gain-unit settings are accurately calculated and adjusted.

3. DESIGN PROCEDURES

Direct Interoffice Trunks

3.01 Prepare a sketch of the recommended circuit layout showing loading spacings, end-sections, and proposed E6 repeater location.

3.02 Calculate the dc resistance of the facility using the appropriate resistance values below.

OHMS PER KILOFOOT AT 68°F

	NL	H88 COILS	TOTAL LOADED
19 ga	16.1	1.5	17.6
22 ga	32.5	1.5	33.9
24 ga	51.9	1.5	53.4
26 ga	83.3	1.5	84.8

3.03 Determine the low-frequency corrector (LFC) settings and building-out resistance (BOR) values for the LBO networks.

(a) On uniform-gauge cables, the LFC is that for the gauge of the cable pair. The BOR values are given in Table A (attached) as a function of the resistance of endsection.

(b) With mixed-gauge endsections, the LFC setting used depends on the predominant cable gauge and the amount of finer-gauge cable used in the endsection. Table B (attached) lists these rules for mixed sections where the finer-gauge pair is adjacent to the office. The BOR values can be determined from the resistance in the endsection, also depending on the LFC setting chosen as given in Table B. The endsection should include all cabling up to the actual repeater location — not just the outside cable endsection.

(c) For mixed-gauge endsections other than those listed, the initial settings can be roughly estimated, to be followed by actual adjustment using the 54C test set.

3.04 Add 40 ohms (the resistance of the line transformer in the gain unit) to the sum of the values obtained in 3.02 and 3.03 plus 25 ohms for each LBO network (one for terminal repeater, two for intermediate). If a gain disabler is specified, add 120 ohms to the result just obtained to account for the dc resistance of the relay in the gain disabler.

3.05 Compare the result obtained in 3.04 with the supervision and signaling limits for the particular trunk relay equipment proposed for this circuit. If the limits are met, proceed to step 3.06. If the limits are exceeded, but can be met by eliminating all or part of the BOR, make a note of this fact and proceed to step 3.06.

3.06 Compute the effective loss of the facility including the LBO on each side of the E6 repeater, using the constants shown in Table C (attached).

(a) If 1000-cps loss measurements are available, subtract any equipment losses which are included in the measurement but which will not be present between the repeater and line, or add office-wiring loss if this has not been included in the measurement. The loss of office cabling may be considered the same as that of an equal length of the same gauge of outside cable. Increase the 1000-cps loss by 3 per cent to obtain effective loss values. If aerial sections are used, however, reduce their 1000-cps loss by 8 per cent.

(1) Add to the line loss the fixed LBO loss (not including BOR) as follows:

0.3 db for an LBO with 19-ga LFC

0.4 db for an LBO with 22-ga LFC

0.5 db for an LBO with 24-ga LFC

(2) If BOR is omitted to increase the signaling range as suggested in 3.05, the sum of the line loss, fixed LBO loss and the office cabling loss is the total loss. If the recommended BOR setting is used, add to the measured line loss the loss of the cable that would be needed to build out the endsection to 5,800 feet. To compute this loss, multiply the effective loss per kilofoot of the loaded facility corresponding to the LFC adjustment, by the difference, in kilofeet, between 5,800 feet and the endsection, including office cabling.

Example: A 22-gauge cable measures 6.7 db, frame to frame at 1000 cps. The endsection at the repeater office is 1500 feet. The office cabling is estimated at 200 and 600 feet, the latter at the repeater office. A 22-gauge LFC is used.

Line Loss 6.7 × 1.03 =	6.9 db
Office cable 800 ft. × .152/1000 ft. =	0.1
Fixed LBO loss 22-ga. LFC =	0.4
BOR + BOC (5.8 − 1.5 − .6) kft × .152 db/1000 ft =	0.6
	8.0 db

(b) If loss measurements are not available, compute the effective loss of the facilities, using the constants given in Table C. Determine the length of endsection at the repeater end and add to the length of the cable section enough to make this a 5800-foot endsection. Multiply this total length by the effective loss per unit length. If the endsection is finer gauge, use the loss corresponding to the LFC setting for the full 5800-foot length. Add 0.3 db for an LBO with a 19-gauge LFC, 0.4 db for 22-gauge LFC, or 0.5 db for 24-gauge LFC.

(1) If the BOR is omitted, as suggested in 3.05, use the actual length of facility, times the loss per unit length, rather than increasing the repeater endsection to 5800 feet.

(2) If aerial sections are involved, reduce their loss by 8 per cent.

3.07 Compute the BOC settings using Table D (attached). The effect of office cabling on the endsection capacitance and the corresponding BOC setting is obtained by increasing the length of office cabling by 50 per cent to account for an average capacitance of 23 mmf per foot. Thus the effective endsection of 3000 feet of outside cable and 200 feet of office wiring is

$$3000 + 200 \times 1.5 = 3300 \text{ feet.}$$

3.08 Determine the line-section return loss at the critical frequency (0.707 times cutoff frequency) on each side of the gain unit of the E6 repeater, using the procedure described in Appendix A to this chapter. Use a value of 0 db for the return loss at both terminals of the circuit unless a gain disabler or idle-circuit termination is specified, in which case use 4.5 db.

3.09 Refer to Fig. 2 to obtain the maximum allowable gain-unit gain. However, if the LBO settings are to be prescribed in advance, and not actually adjusted by using the 54C set with the LBO connected to the cable pair, choose the gain as in Chapter III, par. 4.03, and set the E6 repeater gain (gain unit plus LBO) within that amount.

3.10 To a close approximation, the effective net loss of the circuit in the working condition is equal to the value determined as in 3.06, plus the drop loss at each end of the circuit, plus the loss of all central office equipment at each end of the circuit, up to but not including the source of subscriber-loop transmitter battery supply, ***minus*** the value determined as in 3.09.

3.11 See 2.05 to check crosstalk rating.

3.12 Compute the expected measured 1000-cps net loss of the circuit in accordance with Bell System Practices.

3.13 If the use of more than one E6 or an E6 and E23 is necessary, the maximum gains permissible for over-all stability may be determined if the return losses for the line section between the repeaters are calculated as follows:

(a) Treat the line section between repeaters as a fictitious line that has 1.2 times the actual loss.

(b) Assume that the fictitious line is split into equal parts, each having loss equal to 0.60 times the actual loss between repeaters if two E6's are involved. If an E6 and an E23 are to be used, more total gain can be obtained by assigning somewhat more of the fictitious line to the E6 than to the E23. Assign E23 gains according to E23 practices.

3.14 Record the required data on the circuit layout card, or equivalent, furnished to the central office people who will place the trunk in service. Include LFC setting and estimated BOR and BOC settings for the line A and line B sides.

4. TANDEM TRUNKS (NON-TOLL-COMPLETING)

Use the same design procedure as that recommended for direct interoffice trunks.

5. TERMINAL LINKS

5.01 Use steps 3.01 through 3.14 of the design procedures recommended for direct interoffice trunks.

5.02 Determine the office loss at the ends of the terminal links. At the class 4 or higher-ranking office end of the link, this will include all losses between the point of termination of the intermediate link and the main frame appearance of the cable pair associated with the terminal link. At the class 5 office end of the terminal link, this will include drop loss, switching loss, and the loss of central office equipment up to but not including the source of subscriber-loop battery supply.

5.03 The effective facility loss, plus LBO(s) loss, plus the impedance-compensator loss (assume 0.4 db), plus the office losses obtained in 5.02 above, minus the gain-unit gain, is the effective net loss of the circuit in the working condition.

5.04 See 2.05 to check crosstalk rating.

5.05 Compute the VNL +2 db loss of the circuit by multiplying the main-frame-to-frame length of the facility in miles by a factor of 0.04 db/mi and adding 2.4 db to the result.

5.06 The value obtained in 5.03 above should be no less than the value obtained in 5.05 above. If it is, reduce the proposed gain of the gain unit until agreement is reached.

5.07 The value obtained in 5.03 should be no more than 1 db higher than the value obtained in 5.05.

5.08 Compute the expected measured 1000-cps net loss of the circuit.

5.09 Compute the impedance-compensator building-out capacitor (BOC) setting, using the equivalent capacitance of the cable endsection obtained during cable-acceptance test, if available. Otherwise, use the cable records. Assume a value of 23 micromicrofarads per foot for office wiring and cabling between the main frame and the impedance-compensator location if the actual value has not been determined by measurement.

5.10 Record the required data on the circuit layout card, or equivalent, furnished to the central office people, who will place the trunk in service.

6. DESIGN PROCEDURE FOR TANDEM TRUNK

See Fig. IV-3 for example.

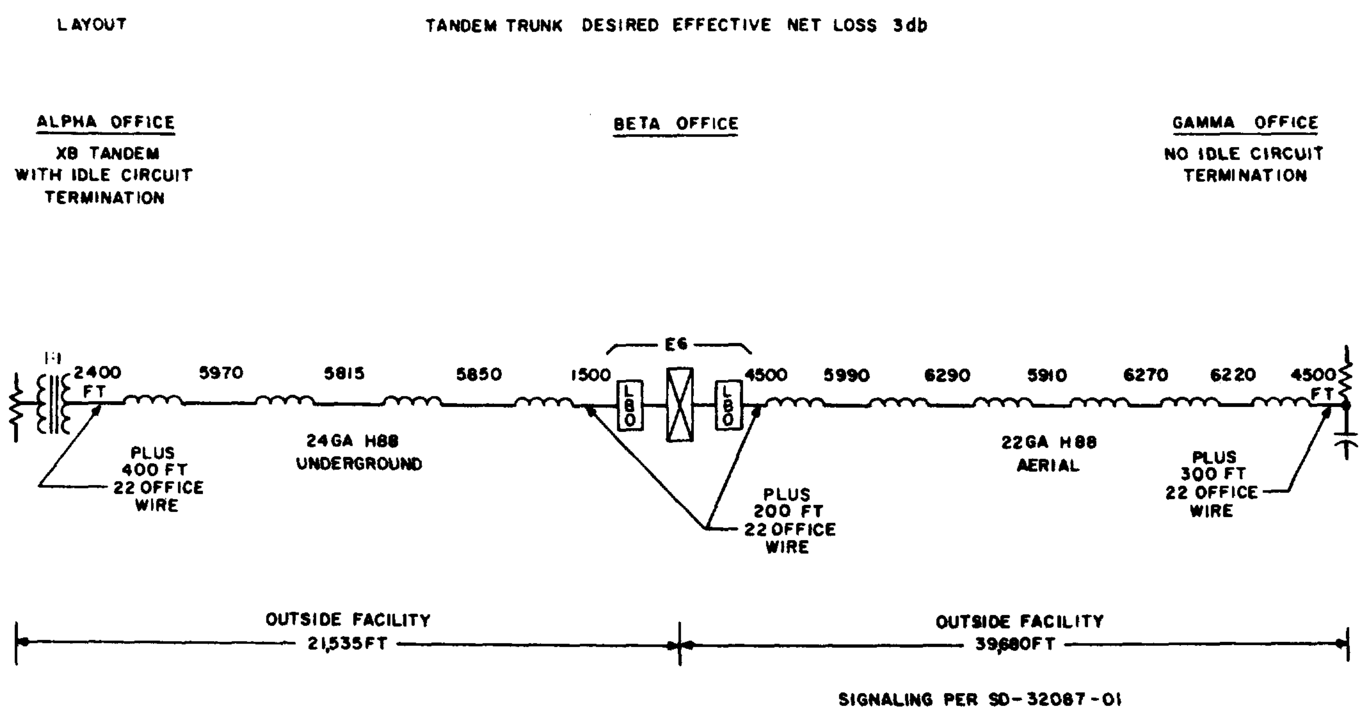


Fig. IV-3 – Layout

Paragraph Reference		Alpha to Beta, Alpha Side of Gain Unit		Beta to Gamma, Gamma Side of Gain Unit	
(3.02)	DC Res of Lines	21.5 x 53.4 =	1150 ohms	39.7 x 33.9 =	1344 ohms
(3.03)	LFC and BOR				
	LFC	24 GA		22 GA	
	BOR				
	Endsection Resistance	1500 x 51.9 =	78 ohms	4500 x 32.5 =	146 ohms
	Office Cable	200 x 32.5 =	7	200 x 32.5 =	7
			85 ohms		153 ohms
	BOR Res (Table A)		112 ohms		0 ohms
	Screws		2,3 & 2,3		1,2,3 & 1,2,3
(3.04)	Total Resistance in Trunk				
	Outside Cable		1150 ohms		1344 ohms
	Office Cable		20		16
	LBO				
	BOR Part		112		0
	Other Part		25		25
	Gain Unit (At Beta Office)		40		-
			1347 ohms		1385 ohms
	Total			2732 ohms	
(3.05)	Signaling Limit for SD-32087-01:		4200 ohms (O.K.)		
(3.06)	Effective Loss				
	Line	21.5 x 0.235 =	5.1 db	39.7 x 0.152 =	6.0 db
	Office Cable	0.6 x 0.152 =	0.1	0.5 x 0.152 =	0.1
	Fixed LBO Loss	(24 GA LFC)	0.5	(22 GA LFC)	0.4
	BOR & BOC	(5.8-1.5-0.2) x 0.235 =	1.0	(5.8-4.5-0.2) x 0.152 =	0.2
			6.7 db		6.7 db
				Aerial Cold: 92%	6.2 db
(3.07)	BOC Settings				
	Endsection	1500 + (1.5 x 200) =	1800 ft	4500 + (1.5 x 200) =	4800 ft
	BOC (Table D)	24 GA, .057	ADG	22 GA, .015	BE
(3.08)	Return Loss Computation (Appendix A)				
	Terminal RL		4.5 db		0 db
	Ref to Gain Unit Location	2 x 6.7 =	13.4	2 x 6.2 =	12.4
	RL at Gain Unit		17.9 db		12.4 db
	Reference Deviation				
		Loading Spacings Feet	Deviations	Loading Spacings Feet	Deviations
		5970	92	5990	146
		5815	63	6290	154
		5850	28	5910	226
				6270	134
				6220	84
	Sum	17635	183	30680	744
	Average	5878	61	6136	149
	Standard	6000		6000	
	Deviation	2.0%	1.0%	2.3%	2.4%
	Reference Deviation	2.4%		3.8%	
	No. Sections Have 3 Times Average Deviation				
	Return Loss (Critical Frequency)				
	Structural RL (Table B, Appendix A)		24.9 db		22.1 db
	Refer to Gain Unit	2 x 1.6 =	3.2	2 x 0.7 =	1.4
	Total		28.1		23.5
	Terminal RL		17.9		12.4
	Difference		10.2		11.1
	Combining Term (Table H, Appendix A)		- 0.4		- 0.3
	Total Line Structural RL		17.5 db		12.1 db
(3.09)	Permissible Gain Unit Gain (Fig. IV-2)			13.0 db	
	Check Overload at Gamma				13.0 db gain
					6.2 db loss
				Level at Output	+ 6.8 db (less than +8 db, O.K.)
(3.10)	Effective Loss of Circuit				
	Cable (at Average Temperature)		6.7 + 6.7 =	13.4 db	
	Office Loss: #5 XBR Tandem			1.1	
	#5 XBR Originating			0.7	
	Total			15.2	
	Desired Effective Loss			3.0	
	Required Gain Unit Gain			12.2	
	Use 12.0 db Gain		Screws	A,B,E,H 1,2,4,5,7,9	

Fig. IV-3 (Cont) — Computations

TABLE A

BOR ADJUSTMENT
FOR OUTSIDE CABLES OF UNIFORM GAUGE

830A Network for H88 High-Capacitance Cable Terminal and Intermediate Repeaters

Note: Resistor screws must always be adjusted in pairs, viz. 1 & 1, 2 & 2, 3 & 3, never singly.

Resistance of Outside End Section Plus Office Cabling (ohms)	Resistance of BOR (ohms)	Screws Down
	19-Gauge Pairs	
0-42	28	1, 2 & 1, 2
43-97	0	All
	22-Gauge Pairs	
0-40	84	1 & 1
41-88	56	1, 3 & 1, 3
89-127	28	1, 2 & 1, 2
128-195	0	All
	24-Gauge Pairs	
0-15	196	None
16-46	168	3 & 3
47-78	140	2 & 2
79-109	112	2, 3 & 2, 3
110-155	84	1 & 1
156-187	56	1, 3 & 1, 3
188-233	28	1, 2 & 1, 2
234-311	0	All

TABLE B

LBO ADJUSTMENTS FOR END SECTIONS CONTAINING FINER-GAUGE CABLE ADJACENT TO THE REPEATER OFFICE

Finer Gauge Adjacent to Repeater Office	Resistance of Finer Gauge Cable Plus Office Cable	LFC Screws	Resistance of End Section + BOR
	Cable Predominantly 19 Gauge		
	(ohms)		(ohms)
22	0-60	19	32-60
	61-195	22	100-128
24	0-31	19	32-60
	32-187	22	100-128
	188-311	24	no BOR
26	0-50	19	32-60
	51-200	22	100-128
	201-500	24	no BOR
	Cable Predominantly 22 Gauge		
	(ohms)		(ohms)
24	0-31	22	100-128
	32-311	24	160-188
26	0-17	22	100-128
	18-500	24	160-188
	Cable Predominantly 24 Gauge		
	(ohms)		(ohms)
26	0-500	24	160-188

TABLE C

LOSSES OF LOADED PAIRS AT 68° F DB/KFT

	1000 CPS	Effective
19 CNB .084 mf/mile H88	.0795	.082
19 DNB .066 mf/mile H88	.072	.074
19 CNB .084 mf/mile D88	.072	.074
22 BSA .082 mf/mile H88	.149	.152
22 BSA .082 mf/mile D88	.132	.134
24 DSM .084 mf/mile H88	.232	.235
24 CSM .072 mf/mile H88	.216	.218
24 DSM .084 mf/mile D88	.191	.206
26 BST .079 mf/mile H88	.340	.35
26 BST .079 mf/mile D88	.306	.314

For aerial sections reduce loss by 8 per cent for effect of low temperatures.

TABLE D

LBO CAPACITOR ADJUSTMENT VERSUS
EQUIVALENT END SECTION OF OUTSIDE CABLE
830A NETWORK FOR H88 HIGH-CAPACITY CABLE
BOTH TERMINAL AND INTERMEDIATE REPEATERS

End Section Length Feet	19 Gauge BOC uf	19 Gauge Screws Down	22 Gauge BOC uf	22 Gauge Screws Down	24 Gauge BOC uf	24 Gauge Screws Down
0	.092	ACEFG	.088	AEFG	.081	DFG
200	.089	BEFG	.084	ABDFG	.079	ACFG
400	.086	ACDFG	.081	DFG	.077	ABFG
600	.083	BDFG	.078	CFG	.074	FG
800	.080	BCFG	.075	AFG	.072	ABDEG
1000	.076	BFG	.072	ABDEG	.069	DEG
1200	.073	CDEG	.069	DEG	.066	CEG
1400	.070	ADEG	.066	CEG	.063	AEG
1600	.066	CEG	.063	AEG	.060	CDG
1800	.063	AEG	.060	CDG	.057	ADG
2000	.060	CDG	.057	ADG	.054	ACG
2200	.057	ADG	.054	ACG	.051	BG
2400	.054	ACG	.051	BG	.048	ABDEF
2600	.051	BG	.048	ABDEF	.046	ADEF
2800	.048	ABDEF	.045	DEF	.043	ACEF
3000	.045	DEF	.042	CEF	.040	BEF
3200	.042	CEF	.040	BEF	.037	ACDF
3400	.038	EF	.037	ACDF	.034	BDF
3600	.035	ABDF	.034	BDF	.032	DF
3800	.032	DF	.031	BCF	.029	CF
4000	.028	ABF	.028	ABF	.026	AF
4200	.025	F	.025	F	.023	ABDE
4400	.022	BDE	.022	BDE	.020	DE
4600	.019	BCE	.018	ACE	.017	CE
4800	.016	ABE	.015	BE	.014	AE
5000	.013	E	.012	ACD	.011	CD
5200	.010	ABD	.009	BD	.008	AD
5400	.007	D	.006	BC	.006	BC
5600	.003	AB	.003	AB	.003	AB
5800 & Over	0	None	0	None	0	None

APPENDIX A

to

CHAPTER IV

ESTIMATION OF LINE SECTION RETURN LOSS

1. GENERAL

1.01 The critical frequency line-section return losses seen at a gain unit are obtained by combining the reflections of such components described in Part 2 as are applicable to the particular layout under consideration.

1.02 The return losses occurring at various points along the line from the distant terminal to the gain unit are referred to their magnitude at the gain-unit terminal. This is done by adding twice the sum of the losses, minus twice any gains between the point of occurrence of the reflection and the gain unit. This process is known as referring a return loss. The referred return losses are then combined on the basis of currents where the minimum return loss is the important factor, or by powers where the average return loss is important, or where the return losses being combined have random phase.

1.03 Echo-return-loss (ERL) data obtained during cable completion tests are the best guide to structural return losses of specific cable complements. Critical-frequency return losses (CFRL) may be estimated from the formula,

$$\text{CFRL} = \text{ERL} - \text{A}$$

where A has the following values:

TYPE OF LOADING	A
H88 HC	6.5 db
D88 HC	8.0 db
H88 LC	8.0 db

2. COMPONENTS OF LINE SECTION RETURN LOSS

Terminal Return Loss

2.01 Select the appropriate value from Table A. In this table, Term. A and Term. B refer to the two offices at the terminal of the circuit. Some intermediate equipment in special-service lines may open the transmission path in the idle condition at a point closer to the repeater than at the end of the circuit. In such instance 0-db terminal return loss should be assumed at the location of this equipment unless a gain disabler is used or an idle-circuit termination is provided at this point. For these cases the appropriate value of terminal return loss should be selected from Table A.

Critical Frequency Cable Structural Return Loss

2.02 A length of loaded facility has a structural return loss which results from the small irregularities distributed along the line. The structural return loss summarizes the effect of random variations in (a) spacing between loading coils, (b) loading coil inductance, and (c) cable pair capacitance. Critical frequency structural return losses for exchange-type loaded facilities are given in Table B (attached) for values of the reference deviation of a particular loading system. The reference deviation is obtained as described in 2.04.

2.03 The structural return losses for loaded facilities given in Table B are based on infinite length lines. If the loss of a loaded

TABLE A

CIRCUIT	GAIN DISABLER	IDLE CIRCUIT TERMINATION AT TERM. A	IDLE CIRCUIT TERMINATION AT TERM. B	ASSUMED TERMINAL RETURN LOSS IN DB AT TERM. A	ASSUMED TERMINAL RETURN LOSS IN DB AT TERM. B
Direct inter-	No	No	No	0	0
office trunk,	No	Yes	No	4.5	0
tandem trunk,	No	No	Yes	0	4.5
or terminal	No	Yes	Yes	4.5	4.5
link	Yes	No	No	0	4.5

facility is less than about 8 db, the structural return loss as obtained from Table B may be increased by a correction obtained from Table C (attached). If a line section is made up of two or more lengths of loaded facilities of the same type which have appreciably different structural return losses, the following procedure may be applied. The structural return loss of each section as found in Table B is corrected for the finite loss of the particular facility length by the use of Table C. The structural return losses for the remote lengths are then referred to the repeater location as described in Part 3. The final values are combined on the power basis as described in Part 4.

Determining the Reference Deviation of a Loading System

2.04 In Table B, which covers structural return losses for exchange-type loaded facilities, the column headings are for reference deviations ranging from 1 to 15 per cent.

2.05 The reference deviation of a loading system is a measure of the combined effect of two types of spacing deviation which are:

(a) ***The departure of the average spacing of the system from the nominal standard spacing for the type of system.***

(b) ***The average of the differences, with signs disregarded, between the individual spacings and the system average spacing.***

The two types of deviation (a) and (b) are used to read the reference deviation value from the chart in Fig. IV-A-1. The average deviation is used in (b) to avoid the more difficult calculation required to obtain the root-mean-square deviation. The chart is constructed in such a way that with a normal distribution of spacing deviations the reference deviation is correctly obtained by this simplified procedure. The elimination of large deviations which are not within the probable spread of a normal distribution will be discussed in 2.06. The separate treatment of such irregularities as individual spacing irregularities has the advantage of taking into account the actual location of the irregularities in the line. As an example of the procedure, consider the following loading system:

	SPACING BETWEEN COILS FEET	SIGN OF DEVIATION	DEVIATION FROM AVG SPACING FEET
	5990	−	130
	6290	+	170
	5910	−	210
	6270	+	150
	6220	+	100
	6040	−	80
Sum	36,720		840
Avg (6)	6120		140
Std	6000	140/6120 = 0.023 = 2.3%	
Devn	120	(2.3% on vertical scale of Fig. IV-A-1)	

120/6000 = 0.02 = 2%

(2% on horizontal scale of Fig. 1)
Reference Deviation = 3.5%

Three times Reference Deviation
(Paragraph 2.06)
3 × 0.035 × 6000 ft = 630 ft

In the above example, a deviation from standard spacing of three times the reference deviation is about 630 feet. Since the largest actual deviation from 6000 feet is 290 feet, there is no reason to consider any of the spacings as individual load spacing irregularities.

Return Loss Due to Large Load Spacing Irregularity

2.06 Load spacings which are longer or shorter than those typical of the remainder of a loading system are likely to occur, for example, when loaded facilities are cross-connected at intermediate offices. Such irregularities may be treated as specific irregularities. To do this requires determining the percentage deviation from average spacing of each irregular load spacing. For layouts which include lengths of both high- and low-capacitance pairs, the spacings should be figured on a capacitance basis, rather than on actual sheath lengths. Pair capacitances per unit length are given in Table D (attached). Specifically, it is proper to treat a load section

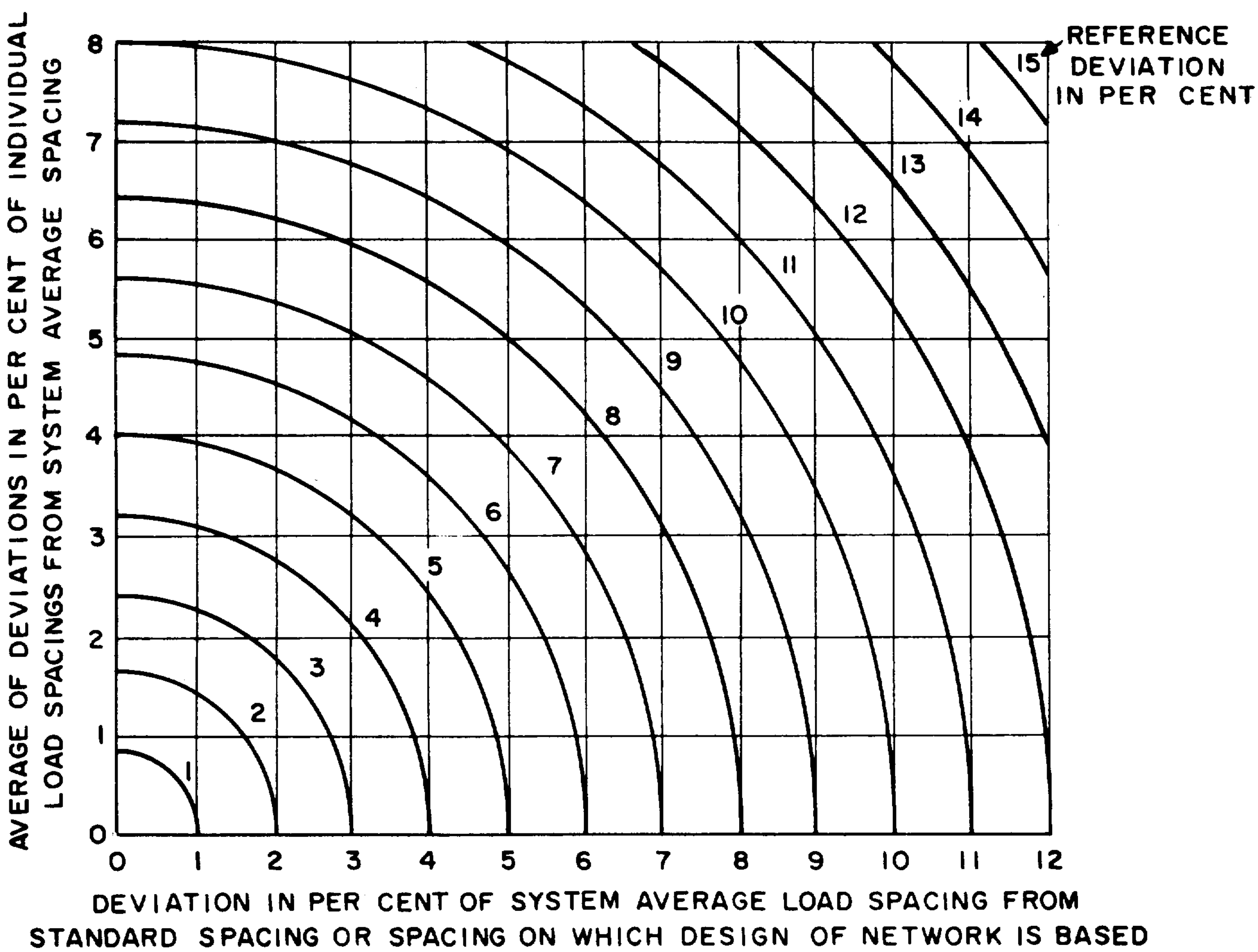


CHART FOR OBTAINING REFERENCE DEVIATION OF A LOADING SYSTEM

Fig. IV-A-1

as an irregularity if its per cent deviation from the nominal standard spacing for the system is greater than about three times the reference deviation of the system remaining, if the irregular spacing is removed from the reference-deviation calculation. Deviations of this magnitude can usually be identified by inspection to avoid making repeated calculations of the reference deviation. Return losses for loading irregularities are given in Table E (attached). These irregularity return losses are based on the per cent deviation of the irregular spacing from the average spacing for the balance of the loading system. For practical purposes the irregularity may be assumed to be at the middle of the irregular section. Each irregularity return loss should be referred to the repeater location as described in Part 3 from the point of its occurrence.

Junction Return Loss

2.07 In some cases line sections will necessarily be made up of more than one type of facility. At a junction between two unlike facilities, a junction return loss occurs because of the discontinuity in line impedance. The ***junction section*** between the two loaded facilities is described as being "normal" if the total capacitance between the two adjoining coils is equal to the sum of the half-section capacitances for the two systems, based on the system average values in each case. Table F (attached) gives junction return losses for ***normal junction sections*** between various types of loaded exchange facilities.

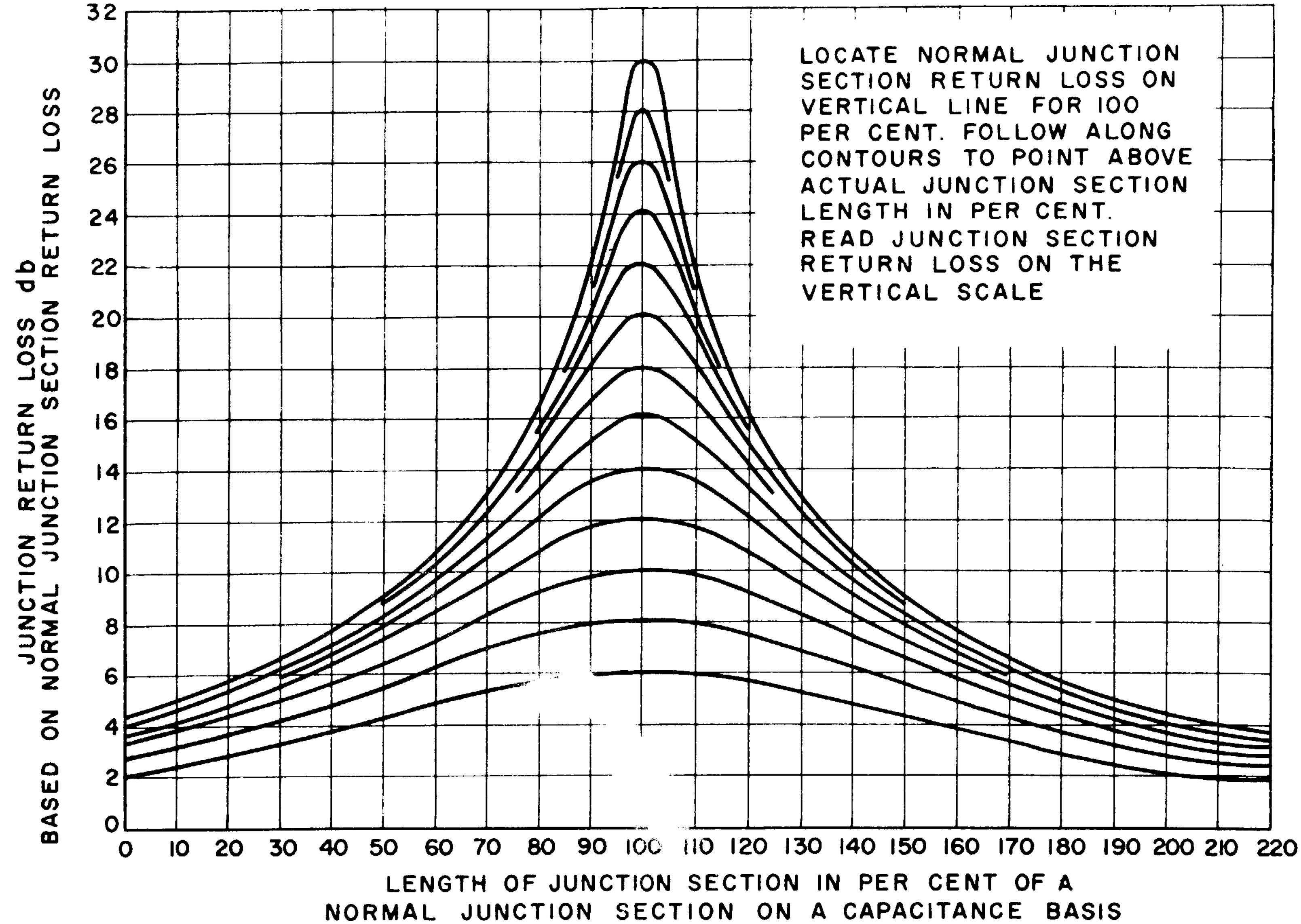
2.08 If a junction section is longer or shorter than "normal," the junction return loss tends to become lower, at least for part of the frequency band. Fig. IV-A-2 has been developed to provide an approximate solution for this effect. In order to read this chart, the total junction section capacitance is expressed as a per cent of the "normal" junction capacitance and considered as a junction section "length." A ***"normal" junction section*** return loss for the joined types of facilities is obtained from the table and spotted on the ***100 per cent*** vertical line of the chart. From this point the contours drawn on the chart are used as a guide to locate a point above the actual per cent "length" of the junction section. The junction-section return loss is then read by referring this point to the vertical scale. For example, consider a junction consisting of 1000 feet of 19-gauge low-capacitance and 5000 feet of 19- high-capacitance facilities, both loaded H88. The "normal" junction return loss for these facilities is 29.5 db, but in this case the normal-section capacitance would be 3 kilofeet times 0.0125 uf/kft plus 3 kilofeet times 0.0159 uf/kft, or 0.0852 uf. The actual junction is 1 times 0.0125 plus 5 times 0.0159, or 0.092 uf. The "per cent" junction is 0.092/0.0852 = 108%. By following just below the 30-db contour to 108%, the return loss is found to be 23 db.

2.09 Junction return losses between loaded and nonloaded facilities are given in Table G (attached).

Intermediate Equipment Return Loss

2.10 The presence of intermediate equipment, which includes repeating coils or bridged retard coils, may be a significant factor in the design of a repeatered line. The maximum effect on line return losses tends to be in the lower-frequency range. At the higher frequencies, the effects will be small, except for the possible case of an inequality-ratio repeating coil. The following rules, which are a compromise between the high- and low-frequency effects, should provide a satisfactory design basis without necessitating return loss computations at two frequencies.

2.11 A repeating coil may be treated as causing an irregularity return loss (at critical frequency) of either (a) about 15 db for the higher-inductance exchange coils, such as the 94E and 120 types, or (b) about 10 db for the lower-inductance coils used in dial pulse repeating circuits, such as the 94N or the older 101A types. In general, bridged retard-coil-type circuits have shunt inductances of at least 0.5 henry. Such coils may be treated as causing irregularity return losses of about 15 db at a similar location. Irregularity return losses caused by equipment are referred to the repeater location as described in Part 3.



JUNCTION SECTION
RETURN LOSS VS LENGTH CHART

Fig. IV-A-2

2.12 For use in making return loss calculations, the following transmission losses for intermediate equipment are suggested:

TYPE OF EQUIPMENT	LOSS
Repeating coil with permalloy core such as 120C	0.3 db
Repeating coil with silicon steel core such as 120CS	0.6 db
Repeating coil of the older general-purpose type such as 94E	0.6 db
Repeating coil used in dial pulse circuit 101A, 94N	0.3 db
Bridged retard coil (0.5 henry or higher)	0.0 db

Return Loss Penalty for Finer-Gauge Endsection

2.13 The LBO takes care of reasonable amounts of finer-gauge cable in the endsection. It will not take care of large amounts without penalty, however. Fig. IV-A-3 shows the best return losses that can be achieved by the best choice of LFC and the best adjustment of BOR. For endsections that give a return loss poorer than 31 db, the gain of the gain unit should not be selected from Fig. IV-2; it should be computed as follows:

(a) Determine from Figure IV-A-3 the best return loss to be expected. If the finer-gauge is not shown, interpolate.

(b) Subtract 5 db.

(c) Combine the result, on a "current" basis, with the return loss of the corresponding line section. If there is finer-gauge cable on both sides of an intermediate repeater, follow this procedure on both sides. If one endsection is the same gauge as the main cable, make no correction on that side.

(d) Add together the resultant return losses of the line section on the two sides of the repeater; use 0 db for the office side of a terminal repeater. One half the sum is the permissible gain of the gain unit. ***Example:*** Intermediate E6 repeater on 22H88 cable except that one endsection (A side) consists of 4 kilofeet of 26-gauge cable.

Line A structural return loss,	24 db
Line A terminal return loss, referred,	12 db
Line B structural return loss,	24 db
Line B terminal return loss, referred,	10 db
Line section A return loss,	11.7 db
Line section B return loss,	9.8 db

(a) From Fig. IV-A-3, return loss of 26-gauge endsection is about 26 db (no greater accuracy is justified)

(b) 26 − 5 = 21 db

(c) Combine 21 db with 11.7 db on a "current" basis . . . . 9.1 db

(d) Gain-unit gain = 1/2(9.8 + 9.1) = 9.5 db

Return Loss Penalty for High-capacitance Endsections

2.14 LBO networks will accommodate endsections up to about 0.090 uf, or the equivalent of 5800 feet of outside cable. Endsections with higher capacitance than this will incur a return loss penalty. See Table E. This is combined with the excess-endsection-resistance return loss on a power basis before the latter is combined on a current basis with the line-section return loss.

3. REFERRING RETURN LOSSES TO A REPEATER LOCATION

3.01 The process of referring a return loss of reflection occurring at any point in a line consists of adding twice the sum of the losses minus twice the gains between the point where the reflection occurs and the gain unit.

3.02 In referring return losses through loaded facilities, use effective losses; through nonloaded facilities, 1-kc losses. In either case, use 92% of the loss at 68°F, to allow for the effects of winter temperatures, which are favorable to singing. Smaller percentages should be taken for areas with unusually severe winters (many days below zero), and larger percentages for areas with little or no freezing weather.

Some metropolitan areas with no aerial cable, and with steam and underground power lines probably fall into the latter class.

RETURN LOSS OF LBO AT CRITICAL FREQUENCY

H88 LOADED CABLE WITH E6 REPEATER

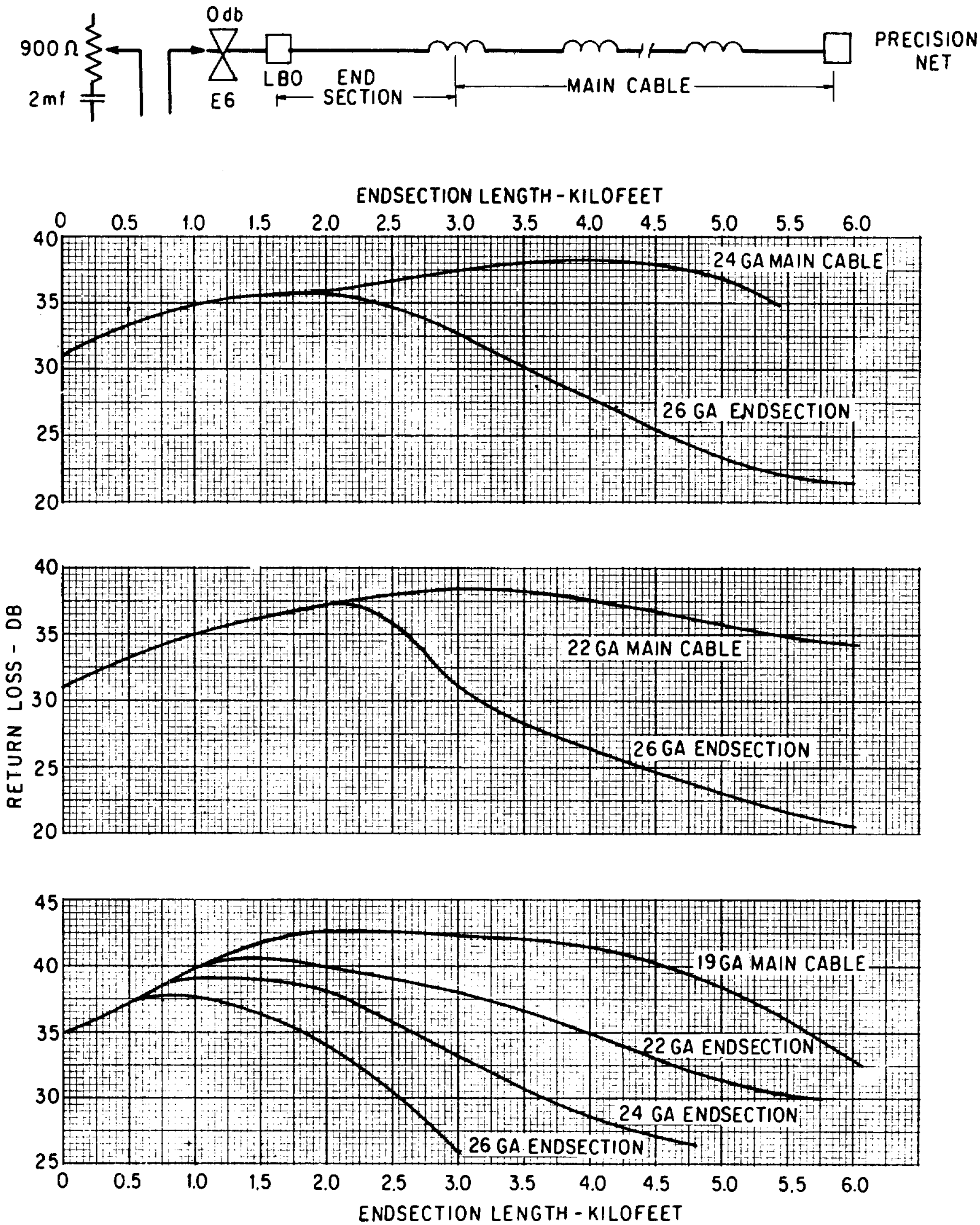


Fig. IV-A-3

4. COMBINING RETURN LOSSES

Power Basis of Combination

4.01 The various referred return losses and the structural return loss applicable to a line section are combined on the power- or energy-summation basis.

4.02 In combining a number of return-loss values, they are selected usually by pairs, as a matter of convenience, starting with the two highest values. From the difference between the two values of the pair a combining term is found in Table H (attached). The combining term is then subtracted from the lower of the two return-loss values of the pair. The result is then treated as a return-loss value in continuing the process. The result for the last remaining pair is the line return loss. As an example, consider the following group of four return losses, all being values referred to the repeater location, i.e., including line, BOR, and LBO loss.

12.8 db
17.4 db
18.6 db
13.4 db

(a) 18.6 − 17.4 = 1.2 db difference
Comb term. = 2.5 db
17.4 − 2.5 = 14.9 db

(b) 14.9 − 13.4 = 1.5 db difference
Comb term. = 2.3 db
13.4 − 2.3 = 11.1 db

(c) 12.8 − 11.1 = 1.7 db difference
Comb term. = 2.2 db
11.1 − 2.2 = 8.9 db (power combination for the group)
Line Return Loss = 8.9 db

"Current" Basis of Combination

4.03 In those cases where the "current" or in-phase basis of combination is required, use the lower part of Table H. Suppose, for example, that a line return loss of 14.6 db is to be combined on a current basis with 26.0 db:

26.0 − 14.6 = 11.4 db difference

Comb term. = 2.1 db

14.6 − 2.1 = 12.5 db (current combination)

Attached:
Tables B through H

TABLE B

STRUCTURAL RETURN LOSSES
FOR STABILITY AND SINGING-MARGIN DESIGN PURPOSES
EXCHANGE AREA FACILITIES

(LONG LENGTHS)

Facility Type	Reference Deviation of Load Spacing (Per Cent)										
	1	2	3	4	5	6	7	8	10	12	15
19LC H88	24.6	23.0	21.1	19.5	17.9	16.6	15.4	14.3	12.6	11.0	9.2
19HC "	25.0	23.4	21.5	19.9	18.3	17.0	15.8	14.7	13.0	11.4	9.6
22 " "	27.2	25.6	23.7	22.1	20.5	19.2	18.0	16.9	15.2	13.6	11.8
24 " "	28.4	26.8	24.9	23.3	21.7	20.4	19.2	18.1	16.4	14.8	13.0
26 " "	29.7	28.1	26.2	24.6	23.0	21.7	20.5	19.4	17.7	16.1	14.3
19HC D88	22.2	20.7	19.2	17.7	16.3	15.0	13.9	12.8	11.1	9.6	7.8
22 " "	24.7	23.2	21.7	20.2	18.8	17.5	16.4	15.3	13.6	12.1	10.3
24 " "	26.0	24.5	23.0	21.5	20.1	18.8	17.7	16.6	14.9	13.4	11.6
26 " "	27.5	26.0	24.5	23.0	21.6	20.3	19.2	18.1	16.4	14.9	13.1

Note 1: The return losses in this table are 63 per cent values at a critical frequency equal to 0.707 times the cutoff frequency. These structural return losses are not suitable for echo design purposes.

Note 2: The designation HC indicates cable with a capacitance of 0.075 uf per mile or greater, and LC indicates cable with a capacitance less than 0.075 uf per mile.

TABLE C

STRUCTURAL RETURN LOSS ADJUSTMENTS FOR SHORT LENGTHS OF LOADED FACILITY

Facility Loss	Correction To Be Added to Structural Return Loss
	db
1.0	4.3
1.5	3.0
2.0	2.1
2.5	1.5
3.0	1.2
3.5	1.0
4.0	0.7
4.5	0.5
5.0	0.4
5.5	0.3
6.0	0.2
6.5	0.2
7.0 to 8.0	0.1
over 8	0

TABLE D

NOMINAL CAPACITANCE OF EXCHANGE AREA CABLES

Cable	Possible Code	uf/mile	uf/kft
19 High Cap.	CNB	0.084	0.0159
19 Low Cap.	DNB	0.066	0.0125
22	BSA	0.082	0.0155
24 High Cap.	DSM	0.084	0.0159
24 Low Cap.	CSM	0.072	0.0136
26	BST	0.079	0.0150

TABLE E

LOADING IRREGULARITY RETURN LOSSES

Per Cent Irreg.	Return Loss db	Per Cent Irreg.	Return Loss db
4	27.9	19	14.5
5	26.0	20	14.1
6	24.6	21	13.7
7	23.1	22	13.3
8	21.9	23	12.9
9	20.9	24	12.6
10	20.0	25	12.3
11	19.2	30	10.8
12	18.4	40	8.6
13	17.8	50	7.0
14	17.1	60	5.8
15	16.5	70	4.8
16	16.0	80	4.2
17	15.5	90	3.6
18	15.0	100	3.0

Note: These irregularity return losses are approximate values based on nondissipative lines at a frequency equal to about 0.7 times the cutoff frequency.

TABLE F

JUNCTION RETURN LOSSES BETWEEN LOADED FACILITIES

	Normal Junction Section Return Losses		
	HC H88	LC H88	HC D88
HC H88	-	-	-
LC H88	29.5 db	-	-
HC D88	24.2 db	28.4 db	-

Note 1: The return loss values in this table are based on midsection impedances of typical grades of plant at either 1000 cycles, or at a frequency near the critical frequency of the lower cutoff facility, according to which return loss is lower.

Note 2: The designation HC indicates cable with a capacitance of 0.075 uf per mile or greater, and LC indicates cable with a capacitance less than 0.075 uf per mile.

TABLE G

JUNCTION RETURN LOSSES
BETWEEN LOADED AND NONLOADED FACILITIES

Loaded Facility	Nonloaded						
	26LC	26HC	24LC	24HC	22C	19LC	19HC
26HC-H88	6.4	6.0	5.0	4.5	3.8	3.1	2.7
24LC-H88	5.6	5.3	4.4	4.1	3.4	2.7	2.5
24HC-H88	6.3	5.8	5.0	4.6	3.8	3.1	2.7
22 -H88	5.9	5.6	4.7	4.4	3.6	3.0	2.6
19LC-H88	4.9	4.6	3.9	3.6	3.0	2.5	2.2
19HC-D88	4.7	4.4	3.8	3.5	2.8	2.4	2.1
19HC-H88	5.8	5.4	4.6	4.3	3.6	2.9	2.6

Note 1: These return losses are based on the midsection impedance of the loaded facility at the critical frequency of that facility.

Note 2: The designation HC indicates cable pairs with a capacitance of 0.075 uf per mile or greater, and LC indicates cable pairs with a capacitance less than 0.075 uf per mile.

TABLE H

COMPUTATION AIDS
COMBINATION OF TWO QUANTITIES IN DECIBELS

When combining gains, add the combining term to the larger; when combining losses, subtract the combining term from the smaller.

COMBINATION ON POWER RATIO (RANDOM) BASIS

Difference Between the Two Quantities	Combining Term	Difference Between the Two Quantities	Combining Term	Difference Between the Two Quantities	Combining Term
0 - .1	3.0	2.2 - 2.4	2.0	5.7 - 6.1	1.0
.2 - .3	2.9	2.5 - 2.7	1.9	6.2 - 6.6	.9
.4 - .5	2.8	2.8 - 3.0	1.8	6.7 - 7.2	.8
.6 - .7	2.7	3.1 - 3.3	1.7	7.3 - 7.9	.7
.8 - .9	2.6	3.4 - 3.6	1.6	8.0 - 8.6	.6
1.0 - 1.2	2.5	3.7 - 4.0	1.5	8.7 - 9.6	.5
1.3 - 1.4	2.4	4.1 - 4.3	1.4	9.7 - 10.7	.4
1.5 - 1.6	2.3	4.4 - 4.7	1.3	10.8 - 12.2	.3
1.7 - 1.9	2.2	4.8 - 5.1	1.2	12.3 - 14.5	.2
2.0 - 2.1	2.1	5.2 - 5.6	1.1	14.6 - 19.3	.1
				19.4 up	0

COMBINATION ON VOLTAGE OR CURRENT RATIO (IN PHASE) BASIS

Difference Between the Two Quantities	Combining Term	Difference Between the Two Quantities	Combining Term	Difference Between the Two Quantities	Combining Term
0 - .1	6.0	4.6 - 4.7	4.0	11.6 - 11.9	2.0
.2 - .3	5.9	4.8 - 5.0	3.9	12.0 - 12.5	1.9
.4 - .5	5.8	5.1 - 5.3	3.8	12.6 - 13.0	1.8
.6 - .7	5.7	5.4 - 5.6	3.7	13.1 - 13.5	1.7
.8 - .9	5.6	5.7 - 5.9	3.6	13.6 - 14.1	1.6
1.0 - 1.1	5.5	6.0 - 6.2	3.5	14.2 - 14.8	1.5
1.2 - 1.3	5.4	6.3 - 6.5	3.4	14.9 - 15.4	1.4
1.4 - 1.6	5.3	6.6 - 6.8	3.3	15.5 - 16.2	1.3
1.7 - 1.8	5.2	6.9 - 7.1	3.2	16.3 - 16.9	1.2
1.9 - 2.0	5.1	7.2 - 7.5	3.1	17.0 - 17.8	1.1
2.1 - 2.2	5.0	7.6 - 7.8	3.0	17.9 - 18.7	1.0
2.3 - 2.5	4.9	7.9 - 8.2	2.9	18.8 - 19.7	.9
2.6 - 2.7	4.8	8.3 - 8.5	2.8	19.8 - 20.9	.8
2.8 - 2.9	4.7	8.6 - 8.9	2.7	21.0 - 22.1	.7
3.0 - 3.2	4.6	9.0 - 9.3	2.6	22.2 - 23.6	.6
3.3 - 3.4	4.5	9.4 - 9.7	2.5	23.7 - 25.4	.5
3.5 - 3.7	4.4	9.8 - 10.1	2.4	25.5 - 27.7	.4
3.8 - 3.9	4.3	10.2 - 10.5	2.3	27.8 - 30.6	.3
4.0 - 4.2	4.2	10.6 - 11.0	2.2	30.7 - 35.1	.2
4.3 - 4.5	4.1	11.1 - 11.5	2.1	35.2 - 44.7	.1
				44.8 up	0

CHAPTER V

TEST SETS AND TEST JACK ARRANGEMENTS

Test Sets for Adjusting and Maintaining the E6 Repeater

Two test sets and a test stand to hold the repeater have been provided to obtain optimum performance from the E6 repeater and to make adjustment fast and easy. The test sets are self-contained and do not require the use of external test apparatus, oscillators, or detectors.

Adjustments of the repeater cannot be made with it in place on the shelf because in this position the adjusting screws are inaccessible. The 54B test stand, shown in Fig. V-1 and V-2, holds the repeater, powers it during adjustment, and permits making connections to various points in the repeater circuit.

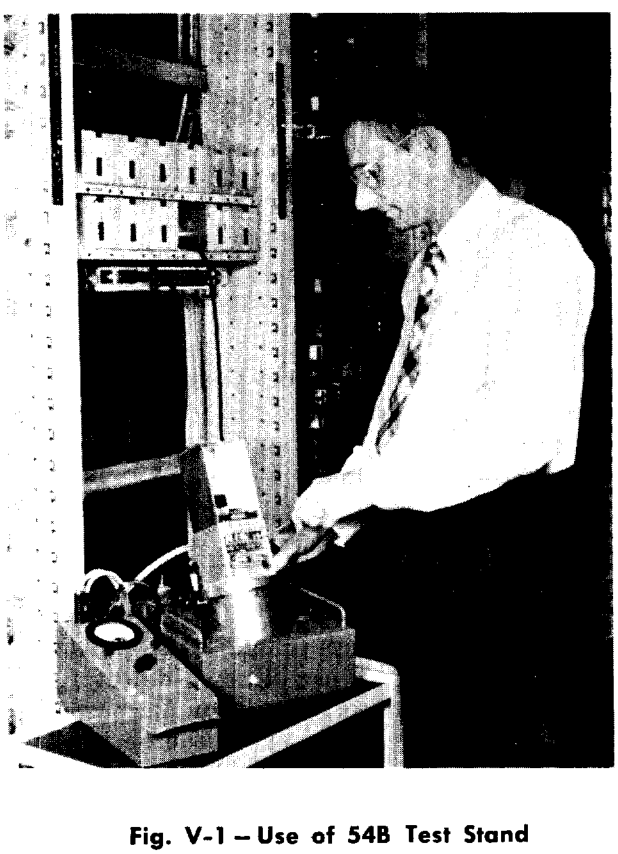


Fig. V-1 – Use of 54B Test Stand

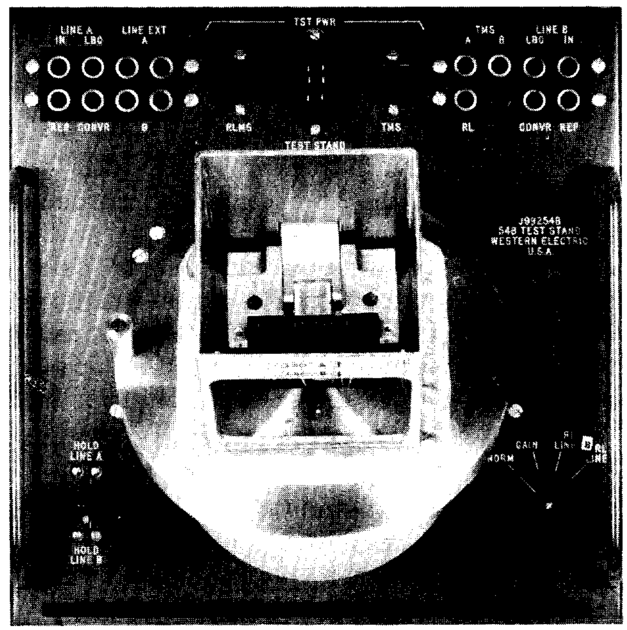


Fig. V-2 – 54B Test Stand

The 54A transmission measuring set is used to adjust the gain and the image impedance of the gain-unit portion of the repeater (See Fig. V-3). The set is used not only during the initial repeater adjustments in conjunction with the 54B test stand, but also to make periodic checks of the gain-unit gain and overload point directly from test jacks on the bays, with the repeaters on the shelf. These tests can be made quickly to reduce repeater out-of-service time. Provision is made for monitoring the circuit for busy conditions just prior to switching the repeater out of the circuit.

The 54A transmission measuring set is not intended for, nor is it suitable for, general transmission measurements.

The 54C return loss measuring set is designed to adjust the LBO network for optimum return loss to compensate for the varying lengths of endsections, office wiring, and for different gauges of cable. This set measures return loss in two bands, either 500 to 2500 cps or 2000 to 3000 cps, with a self-contained sweep-oscillator. Sweep frequencies are used because the relation between return loss and frequency is highly variable and also unpredictable in shape for specific cases. A sweep-frequency measurement gives an average measurement that is much more nearly representative than an arbitrary single-frequency measurement could be.

The 54C set has general-purpose return-loss measuring or adjusting applications other than those with the E6 repeater. It can be used to adjust impedance compensators or precision compromise networks. It can also be used to measure return loss of cable pairs. Provision is made to permit connection of external oscillators, or compromise networks, but no external apparatus is needed for E6 repeater adjustment.

54B Test Stand — J99254B

The 54B test stand is designed to hold an E6 repeater in either of two positions; one position provides access to the gain-unit adjusting screws on one side of the repeater and the other provides access to the LBO network(s) adjusting screws.

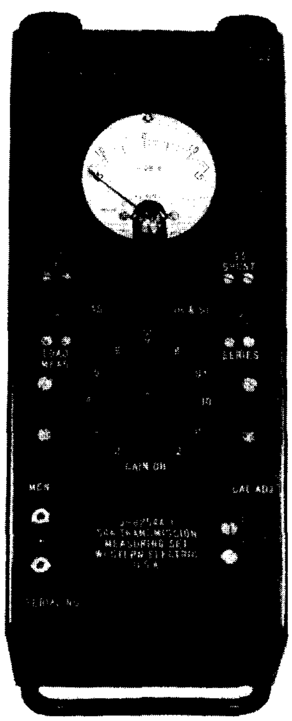


Fig. V-3 – 54A Transmission Measuring Set

A connector cord plugs into the repeater shelf connector jack, extending line A and line B from the shelf jack to the LINE EXT A and LINE EXT B jacks in the test stand. This connection is shown in Fig. V-4. These line terminals are "normaled" through the LINE A IN and REP jacks to the LBO networks. The test stand also provides access to the repeater side of the LBO network and to the gain-unit circuit through the LBO LINE and CONVR jacks which are also normaled through.

The test stand provides a cord for connecting 48-volt power from the repeater bay power jack to the PWR jack of the test stand. The connection furnishes power to the repeater inserted in the test stand and also energizes the TMS power jack and the RLMS power jack. These jacks are used to extend 48-volt power to the 54A transmission measuring set or to the 54C LBO adjusting set.

The test stand contains a switch S1 which connects the gain unit line leads to the CONVR A and CONVR B jacks for the purpose of making gain tests. This connection is shown in Fig. V-5. With the switch on NORM, the repeaters and the LBO's are connected to the lines in the normal manner as shown in Fig. V-4. In the RL LINE A position, the RL jack is connected through the gain unit to the LBO and to line A. In the RL LINE B connection, the RL jack is transferred to the other side of the gain unit through the LBO to line B. This connection is shown in Fig. V-6.

A HOLD key connects a balanced inductor between line A and line B. This provides a 400-ohm dc path for holding dialed-up terminations.

Further details on the 54B test stand are to be found in CD-97025-01 and on SD-97025-01.

54A Transmission Measuring Set — J99254A

This set measures gains from 0.5 db to 13.5 db. It contains an oscillator, a detector, attenuators and a meter circuit to measure the gain of an E6 gain unit, or of the series and shunt units separately. This technique does not require connecting the repeater to the line pairs, as in measuring the gain of an E23 repeater.

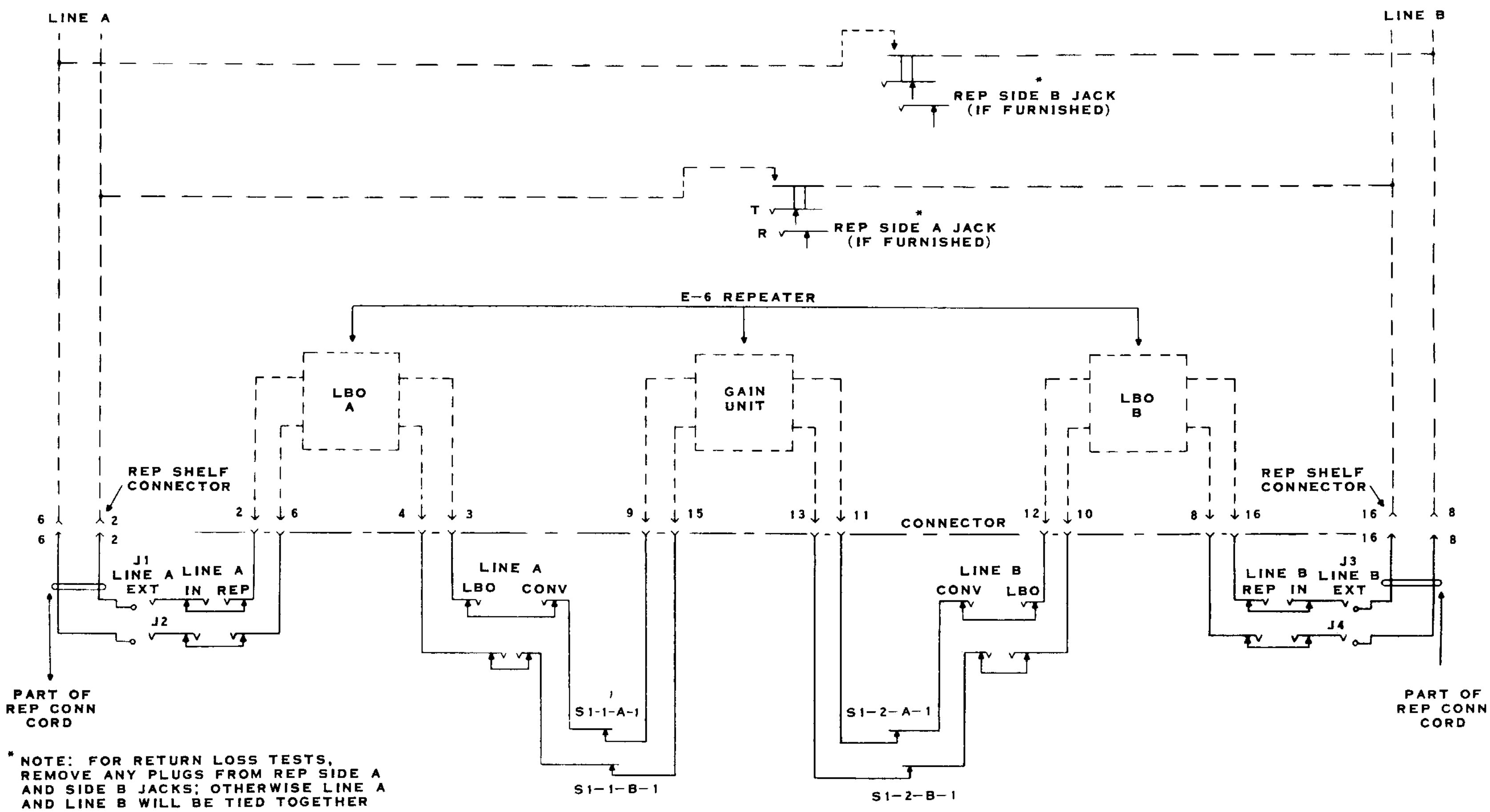


Fig. V-4 – 54B Test Stand Switch and Jack Connections with Switch S1 on NORM

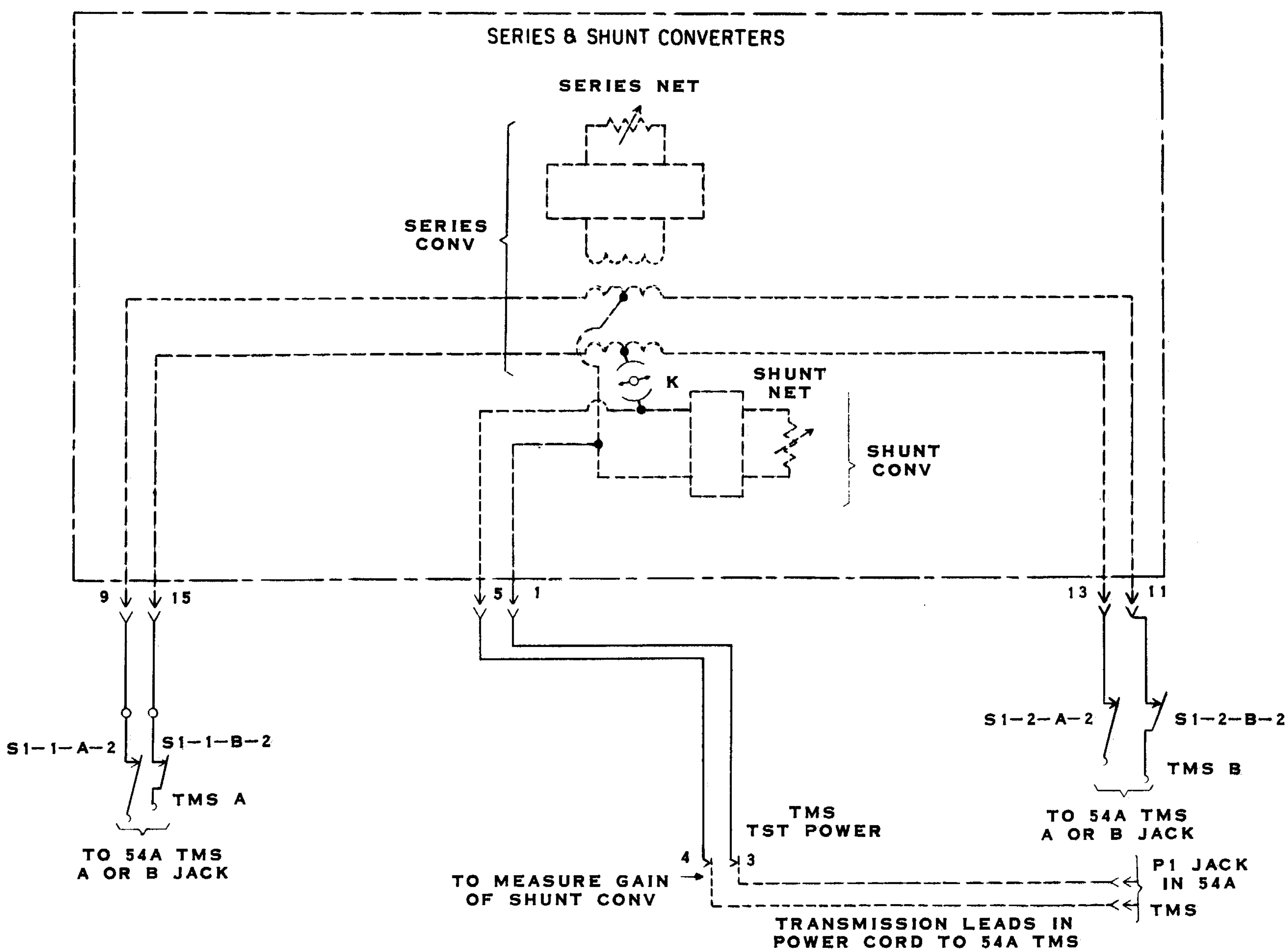
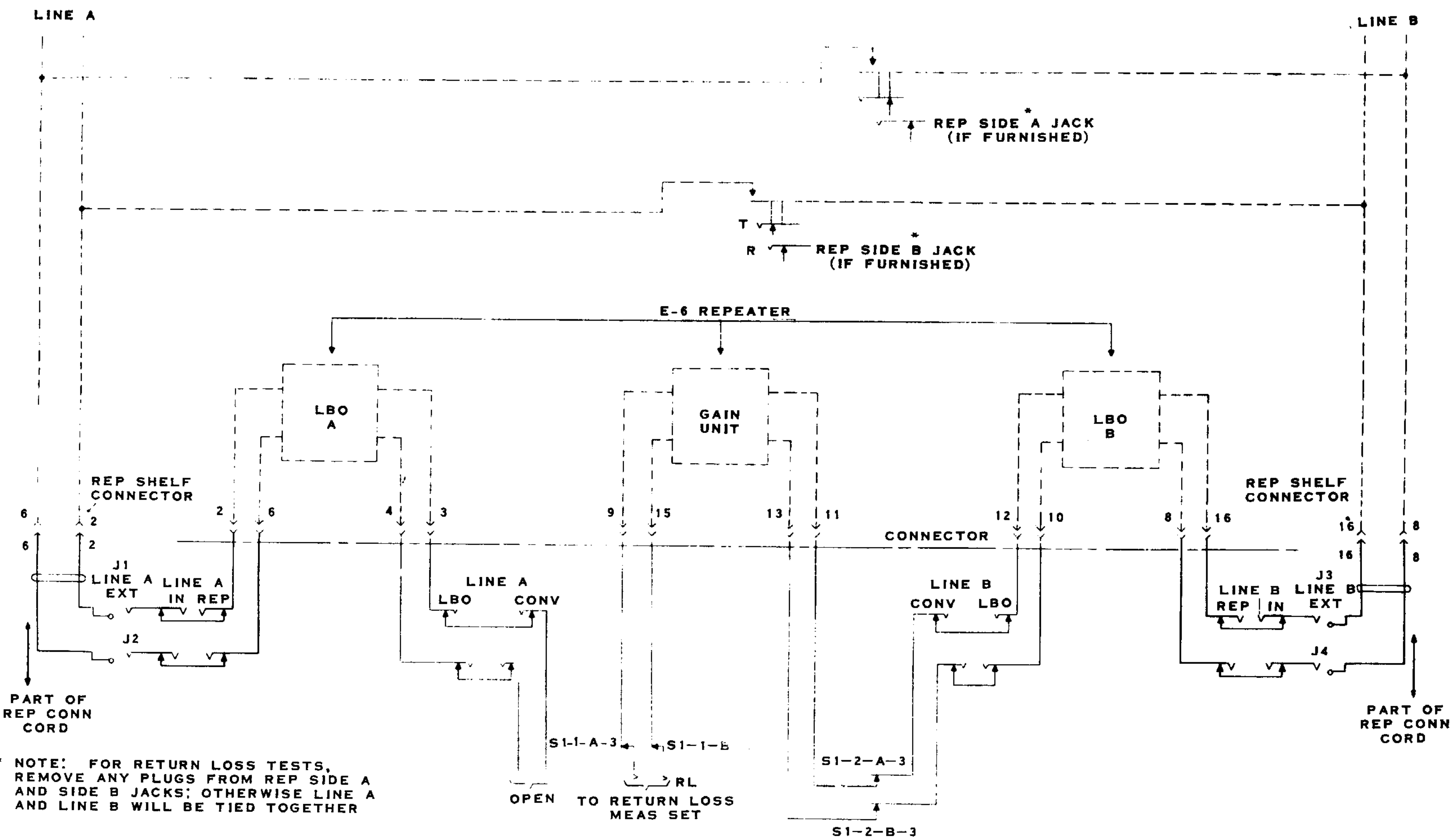


Fig. V-5 – 54B Test Stand Switch and Jack Connections with Switch S1 on GAIN



* NOTE: FOR RETURN LOSS TESTS, REMOVE ANY PLUGS FROM REP SIDE A AND SIDE B JACKS; OTHERWISE LINE A AND LINE B WILL BE TIED TOGETHER

Fig. V-6 – 54B Test Stand Switch and Jack Connections with Switch S1 on RL LINE B

In addition, the test set is equipped to make a high-level gain test just below the overload point of the E6 gain unit. The purpose of this feature is to fully load the transistors and detect possible transistor impairment not evident at low signal levels. The overload test level is automatically adjusted by the 54A gain switch setting to correspond to the overload capabilities of the E6 repeater at different gain settings.

The 54A set is powered from a 48-volt supply either from the power jacks in the 54B test set or directly from the power jacks in the repeater bays.

The set consists of:

(1) A transistor-oscillator with a frequency of approximately 1000 cps, an output power of +13 dbm, and an output impedance of 900 ohms.

(2) Attenuators A and B which adjust the oscillator output to the proper level for low- and high-level gain measurements.

(3) A 1000-cps detector with an input impedance of 900 ohms. Gain is indicated by the sum of the attenuator setting (2 to 12 db in 1-db steps) and meter reading (−1.5 db to +1.5 db in 0.1-db steps). ***The factory sets the meter-adjusting screw by means of a special procedure not easily duplicated in the field. The screw is then sealed so that it cannot be disturbed by mistake. When the detector is not energized, the meter needle should rest firmly against the left-hand stop. This condition is not an indication that the meter needs adjusting.***

(4) A pair of monitoring jacks which permit connection of the KS-14418 head set across the sleeves of the connecting cord when it is partly or fully plugged into the bay test jacks. This feature is provided to permit monitoring in-service circuits before fully inserting the gain-measuring connector plug.

The 491A head set plug also fits the pin jacks in the E6 repeater itself to permit monitoring at the repeater.

The oscillator is an RC-type bridge circuit with the output level stabilized by means of a small tungsten lamp in the bridge. The oscillator circuit uses two transistors. A third power transistor with 12-db local feedback supplies the output power. A factory adjusted rheostat controls the output impedance which is adjusted to 900 ohms.

The detector is a push-pull class B transistor-amplifier with a meter in the common battery lead. Compensation is provided to partially correct for changes in transistor characteristics with temperature. Any deviation in oscillator or detector output level is taken care of by the normal calibration procedure. Frequent calibration, however, is necessary if the 54A test set is subject to large changes in temperature, such as if the set is brought indoors after being exposed to outside temperatures.

An attenuator covers the range of 2- to 12-db repeater gain with the meter on midscale. Repeater gains of 1 and 13 db must be measured using, respectively, the −1 or +1 db points of the meter scale. The switching circuit is arranged so that when S1 is set for any gain value, the input at jack A will be a value so that the repeater output at jack B will be +3 dbm. In general, S1 should be adjusted so that the meter reading falls between 0 and +1 db. The total gain then equals the sum of the gain dial marking plus the meter reading.

Fig. V-7 through 11 show the connections used in calibrating and measuring gain and overload with the 54A set. In order to measure the series and shunt converters separately, it is necessary to open screw K on the gain-unit side of the E6 repeater. After adjusting these two converter networks for equal insertion gain, screw K must be closed before the gain of the combined gain-unit circuit can be measured.

The LOAD MEAS key of the 54A set transfers attenuator B from the input side of the repeater to the output side, thereby applying a high-level signal to the repeater. With good transistors, the gain of the repeater should not drop more than the amount prescribed in the adjustment procedure. Larger gain variations indicate transistor impairment.

An internal adjustment is provided to cause the meter reading to track the gain-adjustment steps. This adjustment is required only when the meter reading fails to indicate a change of 1 db with a tolerance of ±0.1 db for a gain-step change of 1 db. The scale length

FIG. V-7
CALIBRATE

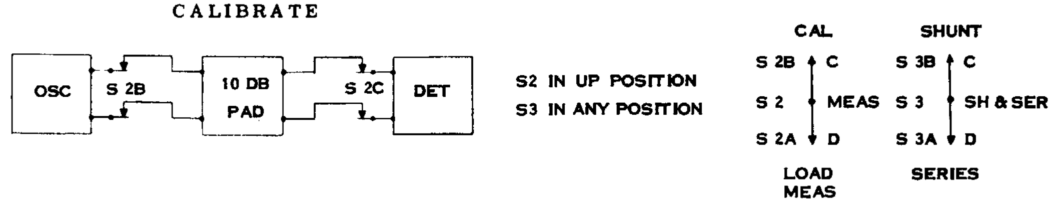


FIG. V-8
SHUNT CONVERTER GAIN

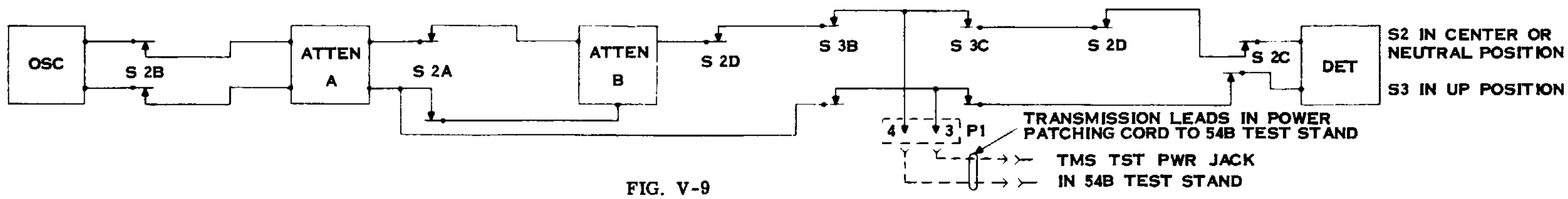


FIG. V-9
SERIES CONVERTER GAIN

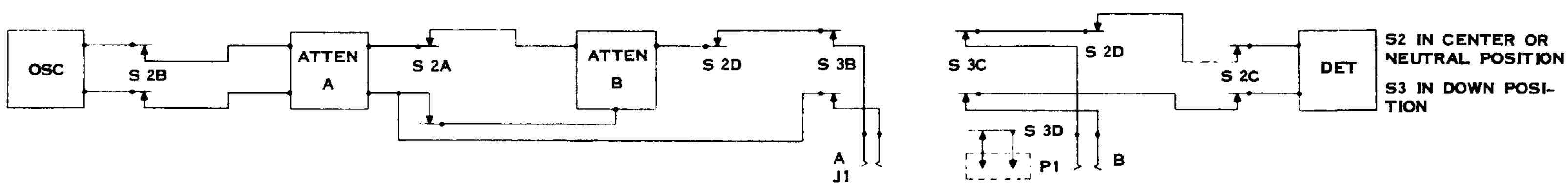


FIG. V-10
COMBINED SHUNT AND SERIES CONVERTER GAIN

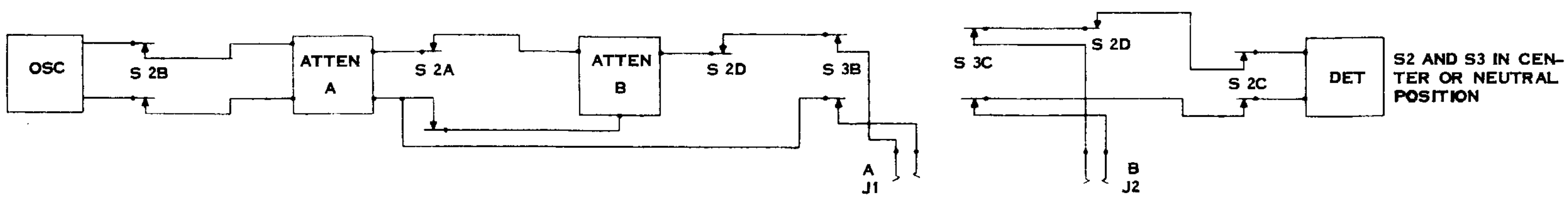


FIG. V-11
COMBINED SHUNT AND SERIES CONVERTER LOAD TEST

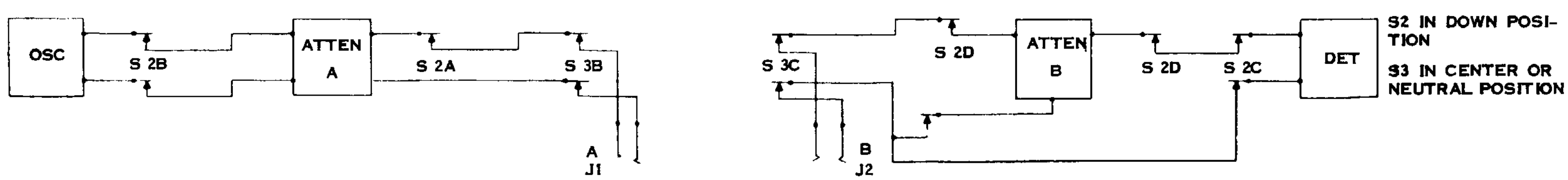


Fig. V-7 through V-11

adjustment requires an accurately known level of signal at 1000 cps from a 900-ohm source. The adjustment is normally made with a +1.5 dbm 1000-cps signal sent into the detector input and a +4.5 dbm input sent into the detector input to read at the −1.5 and +1.5 db points on the meter. The method of adjustment is described in CD-97024-01. It does not require resetting the meter-adjusting screw.

54C Return Loss Measuring Set — J99254C

This set consists of a sweep-oscillator, a detector and meter, a single hybrid transformer and a 900-ohm plus 2.14 uf network. It is used to permit adjustment of the LBO network inserted between the gain unit and the cable pair. This adjustment compensates for length of cable endsection, office cabling, and wire gauge, thereby optimizing the return loss at the gain-unit terminals.

Three connections to the hybrid transformer, namely, OSC, LINE, and NET, are available for external connections, and make the set usable for general return-loss measuring purposes.

The hybrid transformer is a 600-to-10-ohm ratio coil which holds calibration throughout the range of return-loss values measured, between 400 and 3000 cps. It is not designed to operate with direct current flowing through the line windings. Since networks in the 54C sets are "open" to direct current and are used in series with those windings, they automatically protect them from the flow of direct current. If it is necessary to use balancing networks that pass direct current, other measures must be taken to protect the windings.

The sweep-oscillator is a mechanically driven interrupted light system in which a transparent disc is rotated by a small synchronous clock motor. This sweeps a variable-frequency opaque wave pattern photographed on the disc past a phototransistor. The opaque pattern on the disc modulates light falling on the phototransistor. Its output, when amplified, produces the desired sweep frequencies. Two frequency bands are photographed on the rotating disc. The inner band produces a 500- to 2500-cps output which is swept at a uniform rate between these two frequencies. The outside band is a 2000- to 3000-cps sweep. Since the motor shaft rotates at 10 revolutions per second, both bands are swept each 1/10 of a second. The frequencies produced by this system are entirely fixed by the speed of the synchronous motor and by the pattern photographed on the transparent disc. No adjustments of frequency are required.

The detector is a transistor-amplifier and rectifier whose output is fed into the dc meter. The response of the meter and detector is approximately linear to the change in level of the input signals. The meter is shunted by a capacitor which integrates the received energy throughout each 1/10-second sweep, thus producing a nearly constant meter reading. This measures the average return loss over the frequency band being swept.

Calibration to determine the value of the return loss is done by throwing the key to SEND LEVEL CAL, the SWEEP RANGE to 500-2500~, SEND LEVEL ADJ 500-2500~ potentiometer to any convenient reading of the gain attenuator and meter, say 0 db. Restoring the key to MEAS gives the return loss by the difference of the two readings. If, for example, MEAS reads 36 db, the return loss equals 36 minus 0, or 36 db. A separate send-level adjustment is provided for the 2000- to 3000-cps sweep band.

Since a return-loss reading can be thrown into error by noise on the line circuit, a high-pass filter which attenuates frequencies below 200 cps is included in the detector input to reduce the effects of such power-induced noise.

Two cords interconnect the 54B test stand and 54C LBO adjusting set. One is the 48-volt power extension cord, the other, measuring leads. Rotation of switch S1 on the 54B test stand connects the 54C set to the gain unit of the repeater in the test stand, through the LBO network, to either the line A or line B side, as shown in Fig. 6.

Line-section return loss can be measured from the repeater location by use of the 54B test stand and 54C LBO adjusting set. Patch from the 54B test stand either the LINE A IN jack or LINE B IN jack to the MEAS RL jack of the 54C test set. The position of the rotary switch on the 54B test stand has no effect.

The 54C set is capable of measuring return losses from −13 to +45 db over a frequency band of from 200 to 3300 cps with external oscillator.

Repeater Bay Test Jacks

Factory-wired bays for E6 repeaters can be ordered with test jacks which are located about five feet above the floor level. A schematic of the test-jack arrangement is shown in Fig. V-12. These jacks are arranged to pick up the repeater gain-unit terminals and permit gain and overload measurements to be made on the repeaters while the repeaters are in place on the shelves. The jacks do not provide access to the LBO's or to the lines. However, insertion of a dual dummy plug into the two jacks associated with a repeater connects the tip and ring of the two lines through, with the open-circuited LBO's bridged across the pair, thus continuing a talking path without gain. With a plug inserted in these jacks, the repeater can be removed from the shelf without breaking the circuit. The sleeves of each pair of jacks are connected to the tip and ring wires of LINE A. This permits monitoring the line for customer use with the KS-14418 head set before removing the repeater from the circuit.

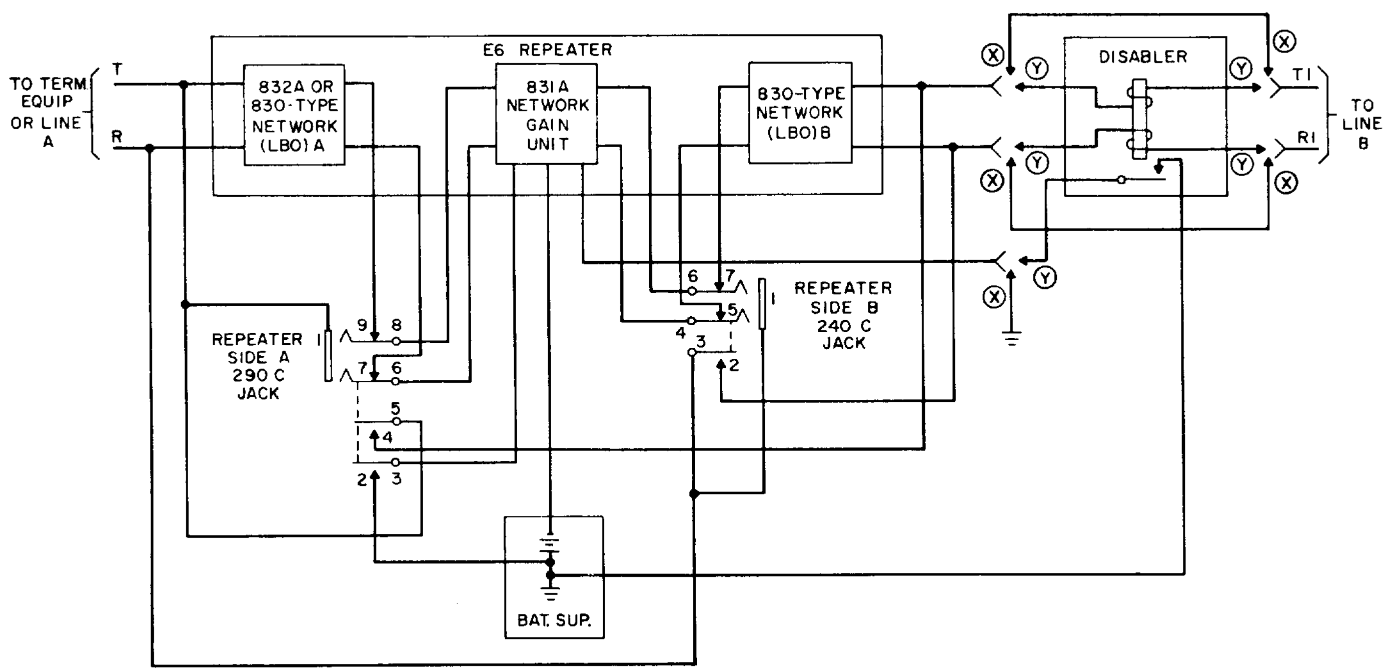
When disablers are wired to the repeater, the insertion of a twin plug in the jacks also connects 48-volt power to the repeater to enable gain tests to be made.

Disabling the Repeater

Several methods of disabling the gain of the E6 repeater are available. The method to be used will depend on the number of repeaters to be disabled and whether it is necessary that the lines be cut through. There is no deterrent to cutting off the power to one or more E6 repeaters since each repeater draws 48-volt power independently of adjacent repeaters.

(1) Insertion of a 491B plug into the TST 1 and TST 2 jacks in front of the repeater. This reduces repeater gain to about 0 db.

(2) Insertion of dummy plugs into bay test jacks. This cuts line through but leaves LBO circuits bridged across the pair, unless



TERMINAL OR INTERMEDIATE E6 REPEATER WITH TEST JACKS AND OPTIONAL DISABLER

Fig. V-12

the repeater is disengaged or removed from shelf. The repeater may sing unless it is disengaged.

(3) Insertion of plug per ED-97023-30, Group 1 (SD-97023-01, Fig. 8) into shelf connector. This cuts lines through but requires removal of repeater from shelf.

(4) Disengagement or removal of repeater from shelf. Open lines.

(5) Removal of fuse on fuse panel. Disables all repeaters on two or three shelves. Cuts in loss on lines, although they are connected through.

Improvised Test Gear

A method of improvising test gear to perform the functions of the 54C return loss measuring set is given in Appendix A to this chapter. The adjustment of the LBO network with this improvised test gear, however, is particularly time-consuming and should not be used after the 54C sets are generally available.

APPENDIX A
to
CHAPTER V

IMPROVISED TEST EQUIPMENT

Substitute for 54C Return Loss Measuring Set

Apparatus that may be used to make the measurements is as follows:

E repeater test set, J98612F or 2G repeater test set, J94002G.

21A transmission measuring set or Hewlett-Packard detector terminated in 600 ohms.

Variable-frequency oscillator, 500 to 2800 cps.

Compromise network, 900 ohms plus 2.14 uf.

Line termination, 900 ohms plus 2.14 uf.

The oscillator frequency must be calibrated at 2800 cps so that the frequency is correct to 100 cps. Output of +10 dbm is the minimum that can be used. An output of +20 dbm is preferred.

The compromise network consists of a 900-ohm (±1 per cent) resistor in series with a 439QA (±2 per cent) capacitor, or two 441QA (±2 per cent) capacitors.

General Procedure

(1) A preliminary adjustment of the LBO adjusting screws should be made to correspond to the best information on the length of the cable endsection, the office cable capacitance, and the cable gauge. Careful adjustment at this point will save considerable time in searching for the optimum LBO capacitor adjustment.

(2) The BOC is first adjusted for the maximum return loss at each of the following frequencies: 2200, 2500, and 2800 cps. (In the 54C set this adjustment is made with the 2000- to 3000-cps sweep band.) In each case, note the BOC values; then set the BOC screws to the average of the three settings.

(3) After the BOC setting has been optimized, the LFC and the BOR adjustments are checked. With the 54C set this is done with the 500- to 2500-cps sweep band. In the improvised method this is done at 500 and 1000 cps; occasionally it may be necessary also to use 1500 cps.

If changes are made from the initial LFC or BOR settings, the BOC adjustment is again checked as in (2).

Specific Procedure

(1) With the E-Repeater test set measure return loss of the gain-unit line terminals, with the other line terminals connected through the LBO and line. Make this measurement against the compromise network consisting of 900 ohms plus 2.14 mf. Terminate the distant end of the line in 900 ohms and 2.14 mf, unless the distant end is a 600-ohm office and terminated in equipment. In this case, use a 600-ohm and 2.14-mf termination. If either terminal is to be equipped with an impedance compensator, this should be connected first and its BOC adjusted before proceeding with the adjustment of the E6 LBO network.

(2) Obtain the maximum return loss by adjusting the BOC screws, using a frequency of 2200 cps. Note the screw settings. Repeat with 2500 cps and with 2800 cps. Translate the screw settings to BOC value using the following table. Add the three BOC values, divide by 3, and use the corresponding screw settings for the LBO adjustment.

BOC Values in 830A Network

(Total capacitance equals sum of screws down)

SCREWS DOWN	CAPACITANCE mf
A	0.001
B	0.002
C	0.004
D	0.007
E	0.013
F	0.025
G	0.049

(3) Measure return loss at 500 cps, and tighten LFC screws one gauge at a time to determine which gauge gives highest return loss. Do the same using 1000 cps. If one gauge gives return-loss results at least 0.5 db higher at both frequencies, use this LFC setting. If not, determine which LFC gauge gives the best result at 1500 cps. Use the setting which gives the best result for two out of the three frequencies. If the difference between the return loss measured with LFC screws is small, use the larger gauge setting, i.e., 22 gauge over 24 gauge, or 19 gauge over 22 gauge.

(4) With the LFC screw adjusted, reset oscillator to 500 cps and obtain the highest return loss by adjusting the BOR screws. ***It is essential that like-numbered screws in the tip and ring sides be set alike.*** Failure to observe this rule may result in high noise when the repeater is put in service. Repeat at 1000 cps. If the same settings give the highest return loss, use these settings. If the difference between the average return loss for two different settings is 0.5 db, use the settings which give the least build-out resistance.

BOR Values in 830A Network

(Total resistance is determined by resistors with screws raised. But table is given in terms of screws tightened.)

SCREWS DOWN	RESISTANCE OHMS
All down	0
1,2 and 1,2	28
1,3 and 1,3	56
1 and 1	84
2,3 and 2,3	112
2 and 2	140
3 and 3	168
None down	196

(5) If a change has been made in LFC setting, or there is a change of more than 28 ohms in the BOR setting, recheck the BOC setting, as given in Step 2.

CHAPTER VI

PUTTING THE REPEATER IN SERVICE

1. GENERAL

1.01 Placing the E6 repeater in service will require some or all of the following steps:

(1) Assembly of the repeater.

(2) Adjustment of the gain unit, check of the gain, and a high-level gain measurement.

(3) LBO network adjustment to fit the line pairs, and measurement of the return loss after adjustment.

(4) Check for singing with the repeater connected to the lines and with various terminations connected at the terminals of the circuit.

1.02 It is assumed that before placing the repeater in service, a cable completion test including an echo structural return-loss measurement was made. Therefore, obvious troubles should have been cleared, or the pairs in trouble should have been rejected for use with repeaters. Such elimination of faulty pairs assures quick installation and avoids difficulties due to missing loading coils or other large unsuspected line irregularities.

1.03 If a repeater is found to be defective, you may return it to the Western Electric Company for correction, as directed by their local representative. It will be helpful if you return only the defective part, that is, the converter unit or an LBO network. The defective part may be determined readily by substitution of parts known to be in good order.

2. ASSEMBLING THE E6 REPEATER

2.01 The E6 repeater gain-unit and connector block are mounted in the aluminum cover before shipment. The LBO networks are shipped separately and mounted in the covers by the Telephone Company. For terminal use, one LBO (830-type) network and one dummy LBO (832A) network are needed. For intermediate use, two LBO's (830-type) are used. The 830-type network slides into the cover and is made fast by four screws on the connector block. These screws also make the required electrical connec-

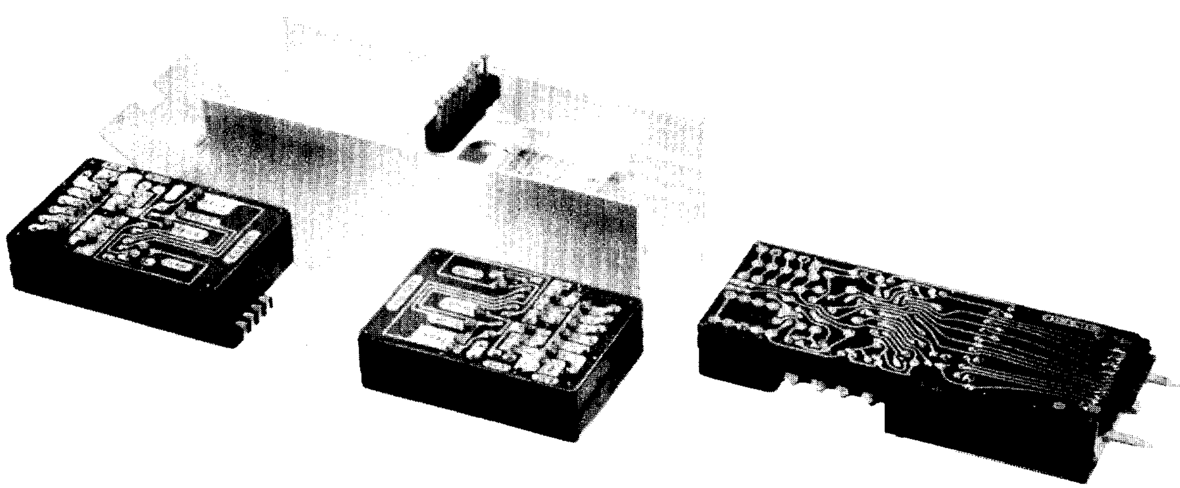


Fig. VI-1

tions between the gain unit and the LBO's. The dummy LBO is relatively small and is secured entirely by the four connecting screws. An exploded view of the repeater is shown in Fig. VI-1.

INTERMEDIATE REPEATERS

2.02 For intermediate repeaters, insert an 830-type network of the type specified for the line-A side. Insert this network over the NETWORK A printing in the repeater cavity. Tighten firmly but not excessively, the four screws that make electrical connection to the 830 network and hold it in the repeater.

Caution: Excessive tightening may strip threads.

2.03 Also insert an 830 network of the type specified for the line-B side and tighten the four screws which hold the network in place over the marking NETWORK B.

TERMINAL REPEATERS

2.04 For terminal repeaters, insert an 830-type network of the type specified for the line-B side and tighten the four screws which hold the network. Insert an 832A (dummy) network on the line-A side of the repeater and tighten these four screws. The terminal repeater assembly is shown in Fig. VI-2.

Caution: Do not attempt to strap the terminals by using wire in place of the use of an 832A dummy network. The screws cannot be driven down with a clearance less than 1/4 inch between the head of the screw and the 831 network without causing internal damage.

ALL REPEATERS

2.05 Turn the repeater over and loosen all screws on the 831A network three turns. These will be labeled A through K, and 1 through 9. See Fig. VI-3.

Note: Certain bus bar connections of the printed wiring of the 831A network adjacent to screw A may appear broken. This is a factory adjustment of individual networks. Do not attempt to close these gaps.

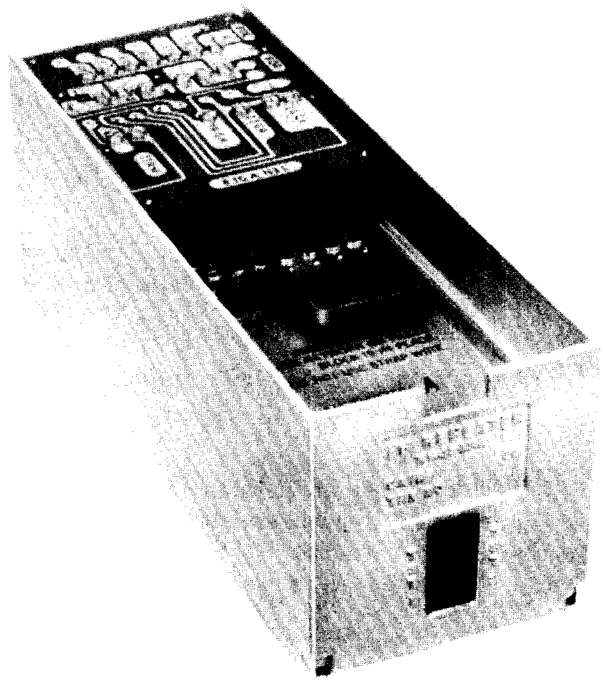


Fig. VI-2

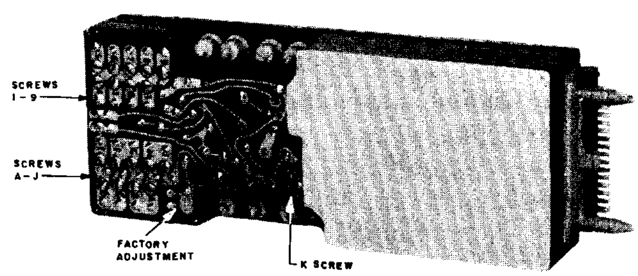


Fig. VI-3

3. MEASURING APPARATUS REQUIRED

1 — 54A transmission measuring set (J99254A, List 1). (The cords under List 2 are not required for initial repeater adjustment. List 2 cords are used for routine gain and high-level checks of the repeater after it has been placed in service.)

1 — 54B test stand (J99254B, List 1) with the cords provided under List 2 as follows:

2 — P5F cords.

2 — 3P7B cords equipped with 310-type plugs at each end for 54A to 54B set.

1 — Cord per ED-97023-30, Group 2 (SD-97023-01, Fig. 2) for repeater shelf to 54B set.

1 — 54C return loss measuring set (J99254C, List 1)

1 — P5F cord for power.

1 — 3P7B cord for 54C to 54B set.

1 — KS-14418 head set equipped with 491A plug.

Terminations at the ends of the circuit per SD-98100-01.

These consist of open-circuit (high-impedance) network, short-circuit (low-impedance) network, and a network consisting either of 900 ohms in series with 2.14 uf or 600 ohms in series with 2.14 uf to be used in 900-ohm and 600-ohm impedance offices, respectively.

12B, 13A, or 21A transmission measuring set (plus 2AB auxiliary transmission measuring set in 900-ohm offices).

Source of 0-dbm, 1000-cps tone at the receiving office. If not available, an oscillator such as 19C or 21A transmission measuring set or Hewlett-Packard oscillator. This should have a 600-ohm output for 600-ohm offices. In addition, 2AB auxiliary transmission measuring set should be used in 900-ohm offices.

4. ADJUSTMENT OF THE REPEATER

GENERAL

4.01 If the trunk is to be equipped with an impedance compensator (at a nonrepeatered terminal), the compensator should be adjusted and connected before E6 repeaters are adjusted.

4.02 Adjustment of the repeater consists of setting the adjusting screws of the gain unit (831A network) and the adjusting screws of the LBO (890 network) and checking both units for performance.

4.03 All adjustments on the 831 gain unit and 830 LBO networks are made by tightening or loosening the screws on the face of the networks. Contact is made by the washers under the screwheads to the printed wiring board conductors. The screwheads should, therefore, be fully down or fully clear of the exposed wiring on the face of the boards.

4.04 Adjustment of the gain unit by means of the 54A transmission measuring set consists of:

(1) Setting screws on the gain unit in accordance with desired gain.

(2) Checking gain of series and shunt converters separately.

(3) Measuring combined gain of the gain-unit converters.

(4) Making a high-level check of the operation of the gain unit.

4.05 The final adjustments of the LBO network are made with the 54C return loss measuring set and consist of:

(1) Setting the LBO screws to preliminary settings based on the gauge of cable, length of endsection, and other line characteristics.

(2) Optimizing these adjustments to give maximum return loss.

ADJUSTMENT OF THE 831A (GAIN UNIT) NETWORK

4.06 Set the 54B test stand and 54A transmission measuring set near the 48-volt power distribution outlet test set power, which is provided on the bays equipped with E6 repeaters.

4.07 Connect from the 48-volt bay power outlet to the 54B test stand and connect the 54B test stand to the 54A transmission measuring set, using the P5F cords. The 54A set is immediately energized. There is no switch to turn power on, nor is there a pilot light. No warmup period is necessary.

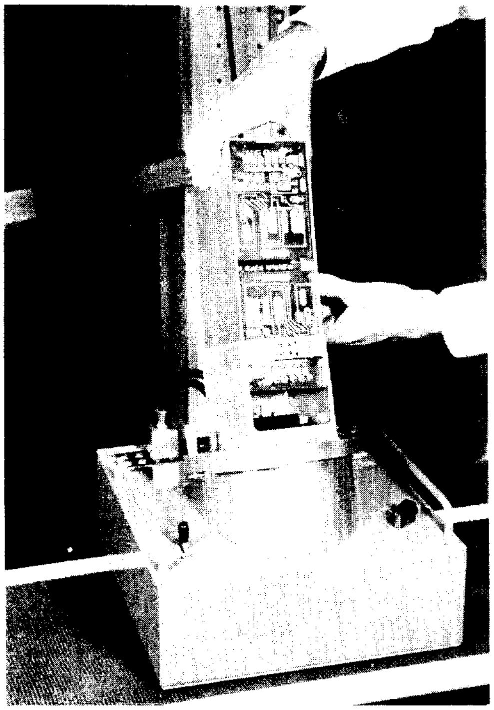


Fig. VI-4

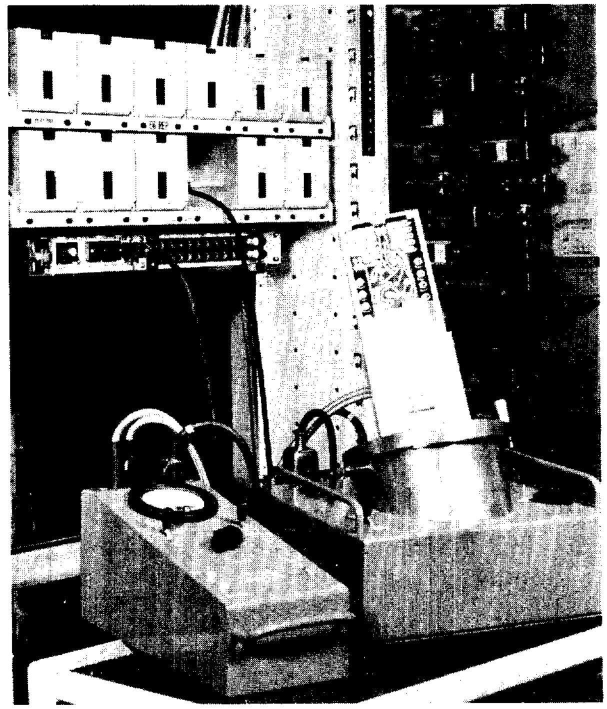


Fig. VI-5

4.08 Connect the TMS A and B jacks of the 54B test stand and the A and B jacks of the 54A transmission measuring set, using the 3P7B cords with 310-type plugs. No connection to the cable pairs is required for the adjustment of the 831A unit.

4.09 Insert the repeater gently into the 54B test stand as shown in Fig. VI-4. The procedure is as follows: Face the 54B test stand. Rotate the head or carriage of the stand so that the knob is at your left hand. Pick up the repeater, plug end down, and rotate it so that the LBO networks face you. Lower ***(do not drop or force)*** the repeater into the stand so that the repeater terminals at the back of the repeater fit into the connector of the test stand. Rotate the head of the 54B set so that the 831A gain-unit side of the repeater is uppermost, as in Fig. VI-5.

4.10 All screws on the gain-unit side should have been loosened, as in 2.05. Consult the circuit layout card for the specified gain adjustment in db. Refer to the 831A network adjustment card in the 54B test stand pocket to determine the necessary screw settings for this specified gain value, as shown in Table A. For gain steps between the 1/2-db steps of Table A, refer to Table B. For example, in the row corresponding to 6-db gain are listed screws A, E, F, J, and 3, 4, 5, 6, 8, to be turned down. Tighten these firmly, but not excessively, and leave all other screws raised.

> ***Caution: Excessive tightening may strip threads.***

4.11 Measure the converter unit gains separately as follows:

(1) Throw S2 on the 54A set to CAL and adjust the knurled knob CAL ADJ to give 0 db reading (See Fig. VI-6.) Release S2. Position of other keys and knobs on the 54A set does not affect this reading. Calibrate frequently.

(2) Rotate gain db knob S1 to 12 db. Be certain screw K on the 831A network is loosened. Operate S3 to SERIES and rotate gain knob S1 counterclockwise until meter reads between 0 and +1 db. The series converter gain equals the sum of the gain-knob setting plus the meter reading. Record this value temporarily.

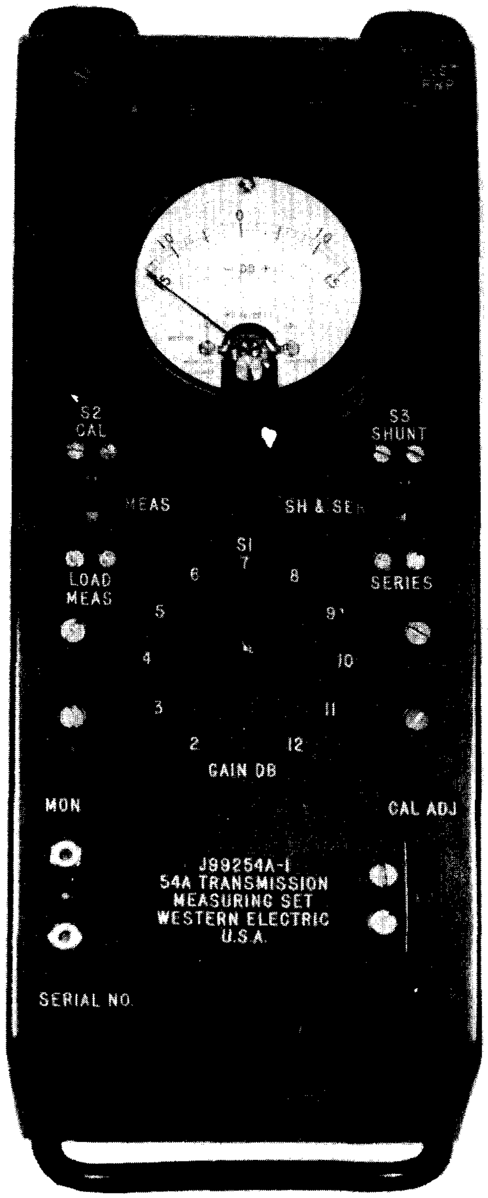


Fig. VI-6

(3) Throw switch S3 from SERIES to SHUNT. Measure and record this gain temporarily.

(4) Compare the two measured gain values with the value given on the 831A network adjustment card in the 54B set pocket for individual converter gains, both sides of which are shown in Table B. For 6 db total gain, for example, the separate converters should measure 3.5 db gain as shown. If both series and shunt gain measurements fall within ±0.2 db of this value and the difference between the two gain readings is less than 0.2 db, proceed to measure the combined gain as described below. If not, adjust the gain of either the series or shunt converter or both as follows.

CONVERTER GAIN READJUSTMENT

4.12 Check to see that the proper screws are turned down and that all others are clear of the printed-card wiring. If no error can be found and the series-converter gain measurement deviates by more than ±0.2 db from the listed value, throw S3 to SERIES. Recalibrate as given in 4.11(1) and then restore S2 to MEAS. Adjust screws A through J on the 831A network to give the tabulated gain for a single converter to within ±0.1 db. Screw A gives the finest gain change; B, C, etc. give larger changes in approximately 2:1 steps. Tightening a screw on the series converter lowers the gain; raising a screw raises the gain.

4.13 If the shunt-converter gain measurement deviates by more than ±0.2 db from the listed value, throw S3 to SHUNT and adjust measured gain to ±0.1 db of listed value, using screws 1 through 9 on the 831A network. Screws 1, 2, etc. are the fine-gain adjustment. Raising a screw on this converter lowers the gain; tightening a screw raises the gain.

COMBINED 831 NETWORK GAIN MEASUREMENT

4.14 The gains of the individual converters must agree with each other within 0.2 db before this step is taken.

4.15 Tighten screw K on the 831A network and leave it in this position. (This screw connects series and shunt converter units together in the operating position.)

4.16 Recalibrate 54A set.

4.17 Throw S3 to SH & SER and measure combined gain. This should check specified gains to within ±0.2 db for gains not exceeding 6 db, and to within ±0.3 db for gains over 6 db. Record the measured gain in pencil in the rectangular recess on the front face of the repeater after the work GAIN.

LOAD CHECK

4.18 With S3 on SH & SER, operate S1 to LOAD MEAS. Note the meter reading, which will decrease slightly. If this decrease is less than 0.4 db, record this second gain measurement after the first measurement on the repeater face. For example, in MEAS 6.0 db, LOAD MEAS 5.8 db, record 6.0 and 5.8. These data will be valuable for future maintenance checks on the repeater.

4.19 Repeaters which fall off in gain more than 0.4 db between MEAS and LOAD MEAS are considered defective. Their converters should be returned to the Western Electric Company as indicated in 1.03.

LINE BUILDING-OUT NETWORK ADJUSTMENT — 830 NETWORK

4.20 The procedure outlined below, starting with Paragraph 4.22, will result in the best performance attainable, if followed for each trunk individually.

4.21 If the facilities in a trunk group are sufficiently alike, screw settings of LBO's for the whole group may be based on the average adjustment for a small sample of trunks, with little sacrifice in performance.

> *Note:* The following paragraphs are written in advance of the manufacture of the 54C return loss measuring set. Certain details and nomenclature may not check with that of final models.

4.22 Patch from the TST PWR jack of the 54C set to RLMS TST PWR jacks of the 54B test stand. Patch from RL jack of the 54B test stand to MEAS RL jack of the 54C set, using a 3P7B cord.

4.23 Have the circuit to be measured turned down at the originating end or at both ends if it is a 2-way trunk.

4.24 Patch from the vacant position on the repeater shelf where the E6 repeater will be installed, to the 54B test stand LINE EXT A & B jacks using the cord, per ED-97023-30, Group 2. Insert the plug gently so as not to damage the shelf-connector spring contacts. Rotate the head of the 54B test stand to bring the 830-type networks forward for easy accessibility. The network connected to line A is uppermost.

BUILDING-OUT CAPACITOR (BOC) ADJUSTMENTS

4.25 If the LBO network on line B is to be adjusted, have the line busied-out but not terminated at the distant office on line B.

4.26 Set switch on 54B test stand to RL LINE B. Set S1 switch on the 54C set to 2000-3000~. If the 54A transmission measuring set is also plugged into the 54B test stand, operate switch S3 to SH & SER. This is required only on early models of the 54B test stand.

4.27 Plug in power cord of 54C set to a 120-volt 60-cycle ac outlet and turn PWR switch on. A 10-minute warmup is required.

4.28 Adjust the gain knob S2 on the 54C set until the meter reads on scale in the MEAS position.

4.29 Set the line B LBO network screws to the preliminary screw settings given on the layout card, tightening the specified screws and loosening all others. If no screw settings are given, start with A, C, E, F, 1, 2, and 1, 2, 22-gauge, and TERM for a terminal repeater. ***For an intermediate repeater raise the TERM screws.*** These suggested initial settings correspond to those for a 22-gauge cable with a 3000-foot endsection.

4.30 Bring the meter on scale by rotating S2 on the 54C set.

4.31 Request a termination at the distant end of line B and observe the meter of the 54C set for a change indicating that the termination has actually been connected to the line being used. This termination is to be 900 ohms in series with 2.14 uf for a 900-ohm impedance office, or 600 ohms in series with 2.14 uf for a 600-ohm impedance office.

4.32 The 54B test stand includes a balanced inductor of 400 ohms resistance to permit holding dialed-up terminations while testing. For this purpose the tester operates a key that inserts the two balanced windings of the inductor in series with the tip and ring wires of the cable pair. A path is thus provided for direct current from one end of the trunk to the other through the test location. At the same time, the two parts of the trunk are isolated at voice frequencies so that neither part affects tests made on the other.

4.33 Optimize the return loss by adjusting BOC screws A through G to obtain the highest return loss. (See 4.35.) Do this by increasing the BOC by 0.004 mf steps; if this causes the return loss to rise, increase the capacitance still further until a maximum is reached. If no maximum is found by increasing the BOC, decrease the capacitance by 0.004 mf steps and follow up until a maximum return loss is obtained.

Note 1: In some cases the adjustment may not be critical. In such cases, use the average of the two settings where a decrease in return loss is just noticeable.

Note 2: If there are two BOC settings which give the same average meter reading, choose the setting for which the meter needle wavers less.

Note 3: Negative values of return loss sometimes occur.

4.34 The values of the BOC screws are as follows:

CAPACITANCE OF BOC SCREWS OF 830A NETWORK ±2%

A	0.001 mf	D	0.007 mf	F	0.025 mf
B	0.002 mf	E	0.013 mf	G	0.049 mf
C	0.004 mf				

Tightening a screw adds capacitance. Thus A, E, F, screws down equals 0.001 plus 0.013 plus 0.025, or 0.039 mf. In this case, 0.004 mf could be added by tightening screw C. To remove 0.004 mf the screws would be A, B, D, F down.

4.35 ***Remove screwdriver from screwheads when observing 54C meter reading.***

LOW-FREQUENCY (LFC) NETWORK ADJUSTMENT

4.36 Set S1 on the 54C set to 500-2500~. Bring reading of meter on scale by rotating gain knob S2. Turn out LBO screw or screws for cable gauge originally selected. Turn in screw for one of the other gauges.

Note 1: The screw setting which gives the greater return-loss value is the best setting, but screw or screws for one gauge only shall be left down.

Note 2: If the setting for two different gauges gives the same results, use the one for the coarser wire, i.e., set for 19 gauge when same results within 0.5 db are obtained on 19 and 22 gauges.

BUILDING-OUT RESISTOR (BOR) ADJUSTMENT

4.37 Set S1 on the 54C set to 500-2500~ sweep. Reduce initial BOR value on LBO to next lower value to check if return loss is increased. If not, increase BOR value.

Note: The condition which gives the greater return-loss value is the best setting. If the same results are obtained for two different values of BOR, set for lower value of resistance. ***Be sure that the same value of resistance is used in the tip and ring side of line, i.e., 1 + 1, 2 + 2, 3 + 3 screws must be in a corresponding position.*** When different values are used, the circuit becomes unbalanced and is susceptible to noise.

4.38 The resistance values which can be obtained are as follows:

All screws down	0 ohms
1, 2 & 1, 2 down	28 ohms
1, 3 & 1, 3 down	56 ohms
1 & 1 down	84 ohms
2, 3 & 2, 3 down	112 ohms
2 & 2 down	140 ohms
3 & 3 down	168 ohms
No screws down	196 ohms

MEASUREMENT OF RETURN LOSS

4.39 When the LBO screw adjustments have been completed, measure the return loss. Throw S3 on the 54C set to CAL, S1 to 500-2500~, and adjust SEND LEVEL ADJ potentiometer for 500-2500~, to the black 0-db reading on meter with the gain knob set on the black 0 db. Throw S3 to MEAS and note the direction the needle moves; counterclockwise motion indicates positive return loss; clockwise negative. Rotate the gain knob to obtain a scale reading between 0 and 10 db. Record the reading of dial and meter, remembering to read the same color on both, and that red means negative.

4.40 Make the same measurement and CAL adjustment with S1 on 2000-3000~, using the 2000-3000 CAL ADJ potentiometer. Record this measurement.

4.41 Release termination at the far end of the circuit.

ADJUSTMENT OF LINE A LBO NETWORK (INTERMEDIATE REPEATERS)

4.42 Follow procedure in 4.25 through 4.37 on the LBO network connected to line A. Procedure is similar except that switch on 54B test stand is turned to RL LINE A and terminations are required at the other office.

4.43 Release termination at far end of circuit.

4.44 Set left-hand switch on 54B to neutral (middle) position. Repeater is now ready for stability tests.

5. STABILITY TESTS (SINGING CHECKS)

5.01 The extent of these tests will depend on whether the circuit is equipped with idle-circuit terminations at neither end, at one end, or at both ends, or is equipped with a repeater disabler. Circuit layout will specify whether the stability checks are to be made from frame to frame or over-all, including office equipment at both ends.

5.02 The tests can be made either with the repeater in the 54B test stand or with the repeater on the shelf. If a test stand is used, set the right-hand switch of the 54B set to NORM.

5.03 Plug the KS-14418 head set into the TST 2 jacks at the front of the repeater. This has less effect on the tendency to sing than using the TST 1 jack.

5.04 Arrange to have short-circuit (low-impedance), open-circuit (high-impedance), and 900-ohm or 600-ohm terminations connected to the terminals of the circuit. If frame-to-frame terminations are specified, these are to be connected at the main frames of the terminating offices. If over-all circuit terminations are specified, these are to be placed on the drop side of the office equipment. Where terminations can be dialed, these may be held after dialing by operating the HOLD key on the 54B set.

5.05 Monitor the repeater for singing with the KS-14418 head set with the following combinations of terminations.

	ORIGINATING END	TERMINATING END
	Circuit Not Equipped with Idle-circuit Terminations or Repeater Disabler	
(1)	900 (600) ohms	900 (600) ohms
(2)	Open circuit	Open circuit
(3)	Open circuit	Short circuit
(4)	Short circuit	Open circuit
(5)	Short circuit	Short circuit
	Circuit Equipped with Idle-circuit Terminations at Both Ends or Repeater Disabler	
(1)	900 (600) ohms	900 (600) ohms
(2)*	Idle condition	Idle condition
(3)	900 (600) ohms	Open circuit

* For circuit with idle-circuit terminations.

	ORIGINATING END	TERMINATING END
	Circuit With Idle-circuit Terminations at One End	
(1)	900 (600) ohms	900 (600) ohms
(2)*	Idle condition	Idle condition
(3)	900 (600) ohms	Open circuit

* Either open circuit or with idle-circuit termination at end equipped with idle-circuit termination.

5.06 If the circuit sings under any of the listed conditions, the trouble must be cleared or the gain reduced. After all trunks have been made stable, test calls and over-all measurements may be made in accordance with other sections of practices.

6. PUTTING REPEATER IN SERVICE

6.01 When a trunk is stable, proceed as follows:

(1) Remove repeater from 54B test stand.

(2) Remove plug from shelf socket.

(3) Plug repeater into shelf. ***Use care, please.***

(4) Have circuit put in service.

TABLE A

E6 CONVERTER NETWORK STRAPPING

Total Gain of Series & Shunt Converters	Gain of Either Series or Shunt Converters	Series Converter Screws Tightened (Closed)									Series Converter Network Totals (Resistance)	Shunt Converter Screws Tightened (Closed)									Shunt Converter Totals (Conductance)
db	db										ohms										umho
1.0	0.5	A			D	E	F		H	J	2,790			3			6				175.4
1.5	0.8		B		D		F		H	J	3,384			3		5	6				254.2
2.0	1.1	A	B		D	E			H	J	3,980	1		3				7			337.2
2.5	1.4	A		C	D				H	J	4,534		2	3		5		7			420.7
3.0	1.7	A	B	C	D	E	F	G		J	5,110		2	3			6	7			497.7
3.5	1.9	A	B	C		E	F	G		J	5,430					5	6	7			547.1
4.0	2.2	A			D		F	G		J	5,984								8		625.0
4.5	2.6				D	E		G		J	6,660	1	2			5			8		718.5
5.0	2.9		B		D			G		J	7,214	1				[illegible]	[illegible]	[illegible]	8		785.7
5.5	3.2		B	C	D	E	F			J	7,700	1	2	3	[illegible]	[illegible]	[illegible]	[illegible]	8		854.3
6.0	3.5	A				E	F			J	8,220		[illegible]	[illegible]	4	5	6		8		918.4
6.5	3.8	A		C			F			J	8,694	1	[illegible]	[illegible]	4			7	8		981.6
7.0	4.2			C		E				J	9,370		2	[illegible]	4	5		7	8		1,065.3
7.5	4.5				D					J	9,844		2	3			6	7	8		1,122.7
8.0	4.9	A			D	E	F	G	H		10,440	1		3		5	6	7	8		1,196.6
8.5	5.2	A		C	D		F	G	H		10,914									9	1,256.3
9.0	5.6	A	B	C	D	E		G	H		11,470		2	3	4					9	1,324.9
9.5	6.0	A				E		G	H		12,030			3	4	5				9	1,393.9
10.0	6.3		B	C				G	H		12,464	1	2	3			6			9	1,446.4
10.5	6.7	A			D	E	F		H		12,990	1		3		5	6			9	1,515.4
11.0	7.1			C	D		F		H		13,504		2					7		9	1,578.6
11.5	7.5						F		H		13,984	1	2	3	4			7		9	1,642.3
12.0	7.9	A	B			E			H		14,500	1	2		4	5		7		9	1,701.5
12.5	8.3				D				H		14,934	1	2	3			6	7		9	1,758.9
13.0	8.7	A		C	D	E	F	G			15,390			3		5	6	7		9	1,823.0
	Ohms	40	80	160	320	634	1,270	2,550	5,110	10,200	Micro-mhos	5	10	20	39	79	156	312	625	1,256	

TABLE B

831A NETWORK ADJUSTMENTS FOR 900-OHM IMAGE IMPEDANCE

Total Gain	Series or Shunt Converter Gain	Series Screws Down	Shunt Screws Down	Total Gain	Series or Shunt Converter Gain	Series Screws Down	Shunt Screws Down
db	db			db	db		
1.0	0.5	ADEFHJ	36	8.2	5.1	AEFGH	1345678
1.1	0.6	CEFHJ	146	8.4	5.2	ACDFGH	9
1.3	0.7	ABCDFHJ	12346	8.6	5.3	ADFGH	129
1.5	0.8	BDFHJ	356	8.7	5.4	BCFGH	1239
1.7	0.9	ACFHJ	1456	8.8	5.5	BFGH	249
1.9	1.0	FHJ	123456	9.0	5.6	ABCDEGH	2349
2.1	1.1	ABDEHJ	137	9.1	5.7	ABDEGH	159
2.2	1.2	BCEHJ	1247	9.2	5.8	ABCEGH	1359
2.4	1.3	BEHJ	157	9.4	5.9	CEGH	1459
2.6	1.4	ACDHJ	2357	9.5	6.0	AEGH	3459
2.8	1.5	DHJ	12457	9.6	6.1	ACDGH	69
3.0	1.6	CHJ	167	9.8	6.2	BDGH	369
3.1	1.7	ABCDEFGJ	2367	9.9	6.3	BCGH	12369
3.3	1.8	ABDEFGJ	12467	10.0	6.4	ABGH	12469
3.4	1.9	ABCEFGJ	567	10.2	6.5	ABCDEFH	23469
3.6	2.0	BEFGJ	13567	10.3	6.6	CDEFH	1569
3.8	2.1	ACDFGJ	124567	10.4	6.7	ADEFH	13569
4.0	2.2	ADFGJ	8	10.6	6.8	BCEFH	4569
4.1	2.3	ACFGJ	138	10.7	6.9	BEFH	124569
4.3	2.4	FGJ	148	10.8	7.0	ABCDFH	1234569
4.4	2.5	CDEGJ	2348	11.0	7.1	CDFH	279
4.6	2.6	DEGJ	1258	11.1	7.2	ADFH	1379
4.8	2.7	ABEGJ	12358	11.2	7.3	BCFH	479
4.9	2.8	ABCDGJ	3458	11.3	7.4	ABFH	12479
5.1	2.9	BDGJ	168	11.5	7.5	FH	123479
5.3	3.0	BCGJ	2368	11.6	7.6	ACDEH	2579
5.4	3.1	BGJ	2468	11.7	7.7	BDEH	13579
5.6	3.2	BCDEFJ	123468	11.8	7.8	ABCEH	4579
5.7	3.3	BDEFJ	12568	12.0	7.9	ABEH	124579
5.8	3.4	ACEFJ	4568	12.1	8.0	AEH	234579
6.0	3.5	AEFJ	34568	12.2	8.1	BCDH	1679
6.1	3.6	ACDFJ	178	12.3	8.2	ABDH	3679
6.3	3.7	ADFJ	1378	12.5	8.3	DH	123679
6.5	3.8	ACFJ	1478	12.6	8.4	ACH	24679
6.6	3.9	AFJ	23478	12.7	8.5	BH	234679
6.7	4.0	CDEJ	2578	12.8	8.6	H	15679
6.9	4.1	DEJ	23578	13.0	8.7	ACDEFG	35679
7.0	4.2	CEJ	24578	13.1	8.8	BDEFG	1235679
7.2	4.3	EJ	234578	13.2	8.9	ABCEFG	245679
7.3	4.4	CDJ	12678	13.3	9.0	CEFG	1345679
7.5	4.5	DJ	23678				
7.6	4.6	CJ	24678				
7.7	4.7	J	234678				
7.9	4.8	CDEFGH	25678				
8.0	4.9	ADEFGH	135678				
8.1	5.0	ACEFGH	145678				

CHAPTER VII

MAINTENANCE

Maintenance tests detect changes in the repeater that have already affected the repeater's performance or that may affect it before the next maintenance tests are made.

For the purpose of checking the transmission performance, certain routine intervals are suggested. The optimum time between these intervals is not now known, and cannot be known until experience has been acquired with the E6 repeater. However, it is believed that the intervals suggested are on the optimistic or long-interval side and for the present should not be lengthened. The suggested routines consist of a twice-yearly monitoring for singing during idle-circuit conditions and a once-yearly check of a gain-unit with normal- and high-signal levels.

There is little that can be done in the field to repair defective components in the E6 repeater within the gain unit or the LBO networks. However, the adjusting screws on the LBO and gain units are interchangeable, and a noncontacting screw can be completely removed and used as a spare in a contacting position if necessary. The piece-part number of these screws with captive washers is P-490842.

In addition to routine maintenance checks, any rearrangements in the outside cable plant or within the office may warrant observing the repeaters for singing, or may require readjustment of the LBO networks, especially if plant changes are made within the first loading section. Extensive outside plant changes such as rerouting may also require readjustment of gain-unit gain and, in some cases, LBO adjustment.

The E6 repeater has been designed and adjusted in the factory for complete interchangeability between the LBO networks and gain units. Thus, if traffic should require the creation of a new trunk using lines already equipped with E6 repeaters, the present LBO's and their adjustment can be preserved and used with the new trunks, so long as a given LBO remains connected to the same cable pair.

It is practicable to duplicate an LBO setting on another LBO unit without making tests. On direct interoffice trunks (losses of over 3 db) settings of a faulty gain unit can also be duplicated on a replacing gain unit without making a gain check. On other types of trunks gain checks should be made.

Routine Maintenance Measurements

Singing Check in Idle Condition

A singing check should correspond with the lowest average cable temperature because singing is most likely when the cable attenuation is low. Singing is determined by monitoring with the KS-14418 head set plugged in across the TST 2 jacks on the front of the repeater (see Fig. VII-1). The TST 1 jacks are at a higher impedance point in the repeater circuit than the TST 2 jacks. The TST 2 jack will have less effect on gain for high-gain repeaters.

Fig. VII-1

Repeaters equipped with disablers cannot sing in the idle-circuit condition because the 48-volt power to the repeater is turned off when there is no dc loop current. A preliminary check of satisfactory singing condition can be made by operating the D relay of the disabler (type B1185), using a toothpick to hold the relay armature operated. The corresponding repeater should then be monitored for singing. The repeater may or may not sing in this condition. If it does not sing, no further test need be made and the toothpick in the disabling relay should be removed. If the repeater does sing in this condition, it will be necessary to have the outgoing terminal office place a call over this circuit to a local telephone in the incoming terminal office. The circuit should not sing either during the ringing period, before answering, or after the called telephone answers. Singing can be detected either at the repeater or at the calling office. Should the repeater sing during either ringing or connected conditions, the same tests on the gain unit and the same corrective action should be taken as described for the repeaters not equipped with the disablers that sing in the idle-circuit condition.

In cases where a repeater does sing, the gain unit should be measured for gain and overload, using the 54A test set. This measurement can be made from the test jacks in the repeater bays if these have been provided. For this test it is not necessary to take the circuit out of service. The monitoring headset is plugged into the 54A test set, and the connection cord and double plug from the 54A test set is partially inserted in the test jacks. (Never insert it too far; it may interrupt a call.) The circuit can then be monitored to determine if it is busy, without removing the repeater. If the circuit is idle, the plug is fully inserted and the gain and load characteristics of the gain unit are measured as described for the 54A test set operation. The measured low-level gain is to be compared with the initial gain which is written in pencil on the repeater face. Changes in gain of less than 0.2 db indicate satisfactory low level operation. The change in gain between the low-level and overload level test should also be less than 0.4 db.

On bays where no test jacks are provided, it will be necessary to make the circuit busy, remove the repeater from the shelf, and use the 54B test stand to make a gain-unit gain and overload test.

E6 gain units that show an overload change greater than 0.4 db should be replaced and suitably marked for return to the repair center. Gain changes due to overload indicate possible deterioration of the transistors. The replacing gain unit should first be adjusted to the same screw settings as the one which is being replaced. Gain of the series converter alone and the shunt converter element (open screw K on 831 network) is then checked against the values indicated on the chart in the 54B test set for the desired over-all gain. If necessary, these are adjusted to within 0.2 db of each other (each within 0.1 db of tabulated value). Screw K on the gain unit is then closed and the complete gain-unit gain is measured. This should check the initial gain of the repeater within ±0.1 db. If necessary, the gain should be adjusted within this tolerance, using the fine-step gain chart to obtain the proper screw settings.

Repeaters that show satisfactory overload but more than 0.4-db change at the normal test level should be readjusted to the original gain settings. This requires a check of equal gain for the series and shunt converters, as described above.

After the gain check, a singing repeater indicates trouble in the LBO network(s), or change in adjustment, or changed outside plant conditions.

It is desirable, if possible, to substitute another E6 repeater adjusted to pairs in the same trunk group for the one which sings. If this repeater also sings, it probably indicates changed outside plant conditions. If the substituted repeater does not sing, it indicates possible trouble in the LBO network or its adjustment.

Assuming that there is no repeater available to substitute for the singing repeater, it is necessary to check the LBO adjustment. This requires a 54B test stand and 54C return loss measuring set. Follow the procedure outlined in Chapter VI for adjusting the LBO network. If it is possible to check the readjusted LBO screw settings against other repeaters in the same group, this should be done. Settings of BOC's within ±0.004 mf, of BOR's within 28 ohms, and the same LFC settings indicate that the cable pair has not changed seriously.

Radically different settings from those of other repeaters or failure to obtain a maximum return-loss setting indicates either trouble in the LBO or changed line conditions. In this case, a new 830 network should be inserted and the LBO readjusted. A radically different setting or failure to obtain a maximum return-loss setting on this second attempt indicates probable line trouble.

Where line trouble is suspected, first check that the distant termination is actually on the circuit. Then have the line checked for opens, shorts, crosses, grounds, and resistance unbalance. Line loss without the repeater can be measured from end to end of the circuit after inserting dummy plugs in the bay test jacks and after disengaging the repeater from the shelf connector. Without test jacks a special plug must be inserted in the shelf connector. (This is connector plug ED-97023-30, Group 1 — SD-97023-01, Fig. 8.)

Irregularities such as bridged taps, missing loading coils, etc., can be located as described in other sections of Bell System Practices.

If the return loss of the line cannot be improved, the only alternative is to reduce the gain of the gain unit to the point where the circuit is stable in the idle-circuit condition.

Circuits equipped with disablers or with idle-circuit terminations can be operated at somewhat lower net loss than circuits not equipped with these devices. A direct trunk can usually be operated at about 2-db lower net loss with a disabler or idle-circuit termination than without it, and tandem or toll trunks at about 1-db lower net loss.

Where a group of repeaters is found to be singing, it should be determined whether the singing repeaters are connected to pairs in one cable or are connected to a single-circuit group. Where a number of repeaters are connected to similar cable pairs and sing, it is a strong indication that there has been some change in the lines or in the office wiring to which the group of repeaters is connected.

Repeaters that sing only in cold weather usually are an indication that the repeater gains were adjusted slightly too high. The only alternative is to reduce the gain and thereby improve the singing margin.

Maintenance Tests for Gain-unit Gain and Overload

These measurements are intended to check that the gain-unit gain has remained at the initially-adjusted value within 0.2 db and that the gain-unit circuit is capable of handling loud speech signals without distortion. The latter measurement gives the transistors a full output workout. This test detects transistor failures which cannot be measured at lower test levels.

Where repeater bay test jacks are installed, the measurements can be made using the 54A transmission measuring set without removing the circuit from service, as shown in Fig. VII-2.

Fig. VII-2

The check is rapid. The KS-14418 monitoring headset is plugged into the MON jacks f the 54A test set. The cords provided under list 2 of J99254A are required. These consist of one 6P1A cord equipped with 338A plugs at each end and one P5F cord for power connection from the PWR jack on the bay to the 54A test set.

Plug the 6P1A cord into jacks A and B of the 54A test set and plug the P5F cord into the power outlet on the bay and into the TEST PWR jack of the 54A test set (see Fig. VII-3).

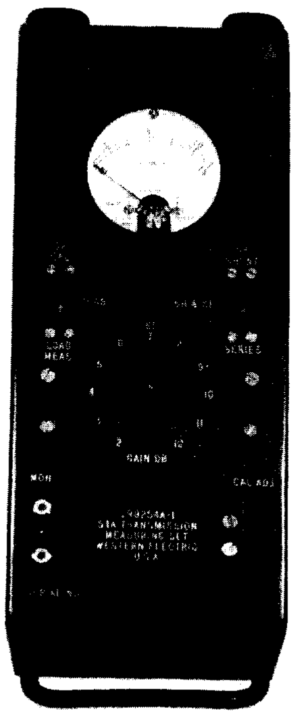


Fig. VII-3

The 54A set is turned on simply by plugging it in. There is neither switch nor pilot light. No warmup time is required.

Operate S2 to CAL and adjust CAL ADJ to bring meter to 0 db.

Release S2, permitting the set to measure. Carefully insert the plug of the monitoring cord part way, at a slight angle, into the test jacks, until the level of the tone drops. This will avoid opening the trunk. Monitor for an idle circuit, and, when it becomes idle, insert the plug fully. Adjust S1 so that meter is between 0 and 1 db on plus side. Note sum of gain setting plus meter reading.

Operate S2 to LOAD MEAS and again note meter reading.

Compare these readings with the two values written in pencil on the repeater which are original MEAS and LOAD MEAS values. Gain units in which the difference from the initial gain as written on the repeater is ±0.2 db or less, and with an overload drop of less than 0.4 db, are satisfactory.

If a greater overload change is found, the gain unit is to be removed, marked, and returned to the repair center. It should be replaced with a new gain unit to be adjusted for equal series and shunt converter gains and with a combined gain within 0.1 db of the initial gain setting.

If the high-load test is satisfactory but the low-level gain differs by 0.2 db or more from the initial gain, the converters may be readjusted. However, if during this test either the series or shunt converter is more than 0.2 db from the gain values tabulated on the chart, this is indication of a defective converter component, and the gain unit should be marked and replaced.

Where no test jacks are provided, it will be necessary to busy-out the circuit before removing each repeater for test and inserting it in a 54B test stand. The 54A test set is connected to the 54B test stand for these measurements.

The original LBO networks can be transferred or associated with a different gain-unit section without readjustment of the LBO networks. Care should be taken that the LBO networks remain in the same position in the repeater housing. The LBO networks should remain connected either to the line A or line B sides of the repeater as for the original repeater.

Specific Troubles

The foregoing sections on singing and gain checks cover the procedures for most specific troubles where singing or improper repeater gain is observed. If an over-all 1000-cycle net-loss measurement indicates that the circuit is not within specified limits, it is desirable to first check gain-unit gain. If this checks with the initial gain setting, it will then be necessary to measure the loss of each cable section separately to determine whether there has been a change in loss. Significant changes in cable loss may cause singing, especially if the change is made close to the repeater. However, they may not cause singing if they are located far from the repeater. Return-loss measurements on the facilities themselves are very sensitive to irregularities and will indicate line changes not easily observed by loss measurements. Return-loss measurements of the kind made during cable acceptance tests are good means of comparison for indicating line changes.

CHAPTER VIII

THEORY

A complete E6 repeater inserted between two sections of loaded cable is shown in Fig. VIII-1. The 830 networks are LBO networks and are designed to transform the input impedance of the cable pair to a fixed value of 900 ohms in series with a 2-uf capacitance which the gain unit faces. Each 830 network is designed for a particular kind of loading and cable capacitance with adjustments for various end-section lengths and conductor gauges.

The LBO network also presents an impedance to the cable pair which is closely equal to the complement of the loaded cable endsection. If, for example, the endsection of the cable is one quarter of a full section, the LBO network appears in impedance as a three-quarter cable endsection. At one-half cable endsection, the LBO has an impedance equal to one-half endsection of cable. For a three-quarter cable endsection, the LBO network appears as a one-quarter endsection of cable. This gives optimum return loss at the remote ends of the cable which is important to control echo and singing on circuits operated at low net loss.

The 830 network is composed only of passive resistor, capacitor, and inductor elements.

The gain-unit circuit is the active amplifier portion of the repeater. It is adjusted to have an image impedance of 900 ohms in series with 2 uf, which is the impedance of the LBO network. It is also the impedance of compromise hybrid networks used at exchange switching points. The gain unit corresponds to a 4-terminal gain pad adjustable from 1 to 13 db with an image impedance matching that of the LBO networks.

When the E6 repeater is used at a switching point as a terminal repeater, one LBO network is omitted. The office switches connect directly to the gain-unit terminals on this side. This is shown in Fig. VIII-2. One LBO network is required between the gain unit and the cable pair.

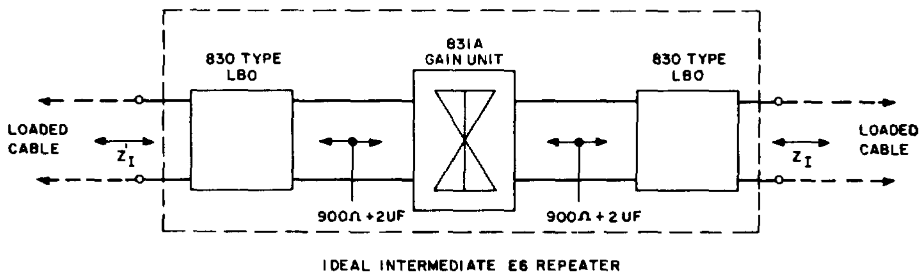


Fig. VIII-1

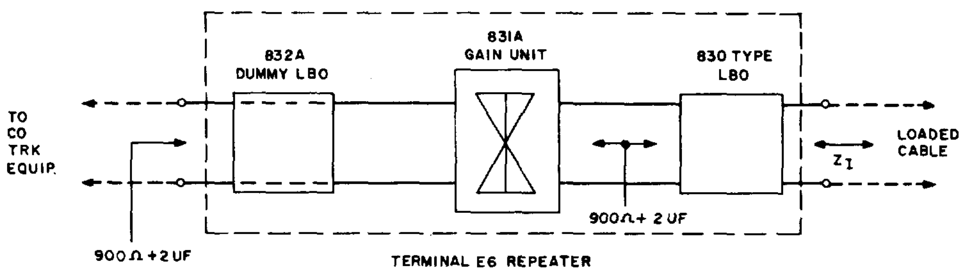


Fig. VIII-2

Gain-unit Circuit

The gain-unit circuit is composed of two active negative-impedance converters connected in a bridged-T arrangement. One negative-impedance converter is essentially connected in series with the cable pair while the other is connected across the midpoints of the line transformer.

The series-connected converter is itself a 4-terminal circuit. Its impedance at one pair of terminals is the negative of that connected across the second pair of terminals. In the E6 repeater this positive impedance or network is composed only of resistors which are adjustable in value. This series-connected converter is "open-circuit stable," meaning that if the line terminals are left open-circuited, the device will not oscillate or sing.

It has long been known that it is possible to obtain circuits with this property of converting positive to negative impedances by coupling the output of an amplifier back to its input. Consider a special kind of amplifier having a current amplification ratio of K, an input impedance of nearly zero, and an output impedance of very high value. By connecting the amplifier as shown in Fig. VIII-3, an open-circuit-stable negative impedance is seen at the source terminals AB.

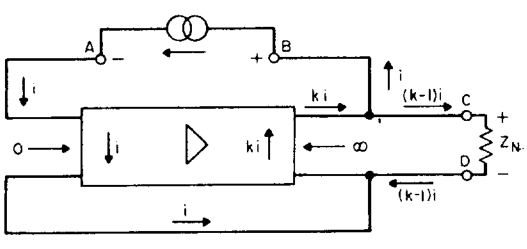


Fig. VIII-3

The voltage across CD = $iZ_N(k-1)$, and since the input impedance is nearly zero, the voltage between B and A also equals $iZ_N(k-1)$. The magnitude of impedance at AB = $\frac{iZ_N(k-1)}{i}$ = $Z_N(k-1)$, but note that the direction of current and voltages at AB is such that the energy is being fed into the source, ***not*** taken from it. Therefore, the impedance of the circuit is negative and $Z_{AB} = -Z_N(k-1)$.

Also note that if terminals AB are open-circuited, the feedback between output and input is opened and the amplifier remains stable.

The input and output impedances of a common base transistor-amplifier closely approximate the amplifier described above; the input impedance is low, the output impedance very high, and the current ratio between emitter and collector very nearly equals 1.

The circuit in Fig. VIII-3 then looks like that shown in Fig. VIII-4.

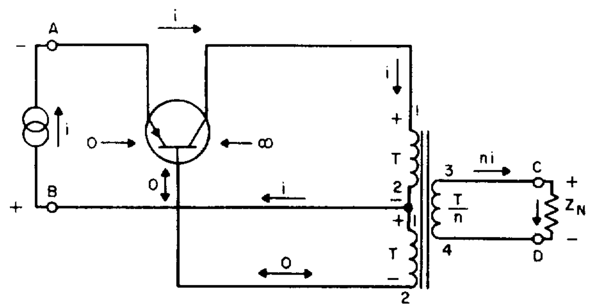


Fig. VIII-4

If n is the turn ratio of the transformer, then voltage across CD will equal inZ_N.

The voltage across each winding T = in^2Z_N and the voltage across AB = in^2Z_N with the sign shown. The impedance at AB = $-\frac{in^2Z_N}{i}$
The circuit is open-circuit stable, for if AB is open there is no feedback from output to input.

By interchanging Z_N and the external circuit, the following relation exists:

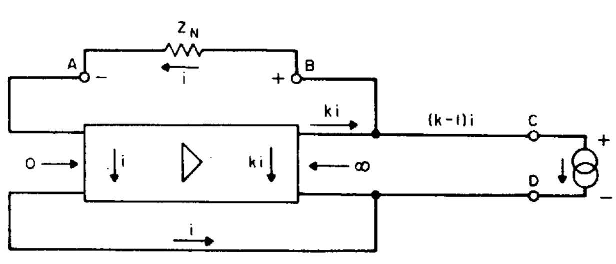


Fig. VIII-5

Voltage BA = iZ_N
Voltage CD = iZ_N
Impedance CD = $\frac{iZ_N}{(k-1)i}$

Opening the external circuit at CD will still permit feedback between output and input, but if CD is short-circuited no voltage can develop across CD and the circuit will remain stable.

The corresponding transistor circuit is

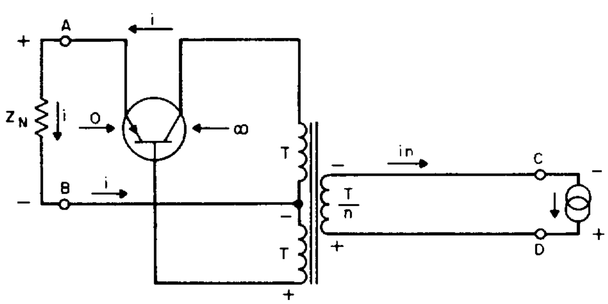


Fig. VIII-6

Voltage across AB = iZ_N; across DC = $\frac{iZ_N}{n}$

$$Z_{CD} = -\frac{\frac{iZ_N}{n}}{in} = -\frac{Z_N}{n^2}$$

Note that a short circuit across CD means zero voltage across winding T.

If a series negative impedance of the type shown in Fig. VIII-3 or VIII-4 is inserted in a line, it increases the current through the line but creates a large impedance irregularity at the point where it is inserted. The circuit remains stable as long as the sum of the resistance components of Z_{L_1} and Z_{L_2} is larger than the magnitude of the negative resistance of Z_S.

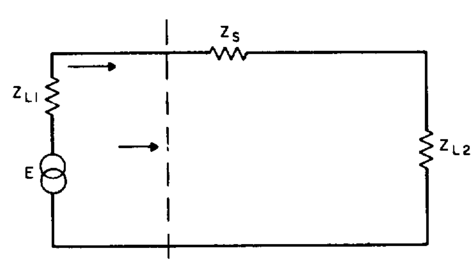


Fig. VIII-7

The gain due to inserting

$$-Z_S = \frac{i_2}{i_1} = \frac{Z_{L_1} + Z_{L_2}}{Z_{L_1} + Z_{L_2} - Z_S}$$

As an example, if

$$Z_{L_1} = Z_{L_2} \text{ and } |-Z_S| = Z_L$$

then

$$\frac{i_2}{i_1} = \frac{2Z_L}{2Z_L - Z_L} = 2\text{, or 6-db gain in current}$$

delivered to Z_{L_2}.

The impedance at the point of insertion of this series negative impedance equals $Z_L - Z_L$ or 0 ohms and there is 100 per cent reflection or 0-db return loss at this point in the circuit for 6-db gain.

Likewise, a shunt negative impedance of the short-circuit stable type can be inserted across the circuit to give gain. This circuit is stable as long as the magnitude of the conductance of $-Z_{SH}$ is less than the sum of the conductance of L1 and L2. The current gain of the circuit $= \frac{(Z_{L_1} + Z_{L_2})(-Z_{SH})}{(Z_{L_1} + Z_{L_2})(-Z_{SH}) + Z_{L_1} Z_{L_2}}$

Again, if $Z_{L_1} = Z_{L_2} = |-Z_{SH}|$ the gain equals 2 or 6 db, and the impedance at the amplifier junction is infinite, giving 100 per cent reflection or 0-db return loss.

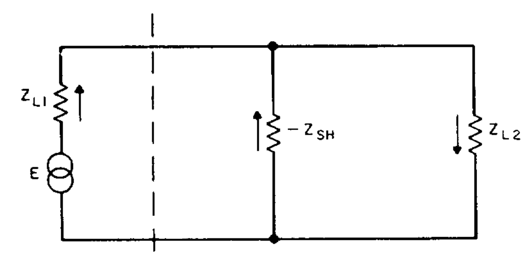


Fig. VIII-8

Thus, negative impedance inserted in series with a circuit lowers the impedance and increases the current from the generator. Shunt negative impedance raises the impedance of the circuit and decreases the current from the generator.

The two types of impedance can be combined in a bridged T structure with control of both the image impedance and gain by varying the values of Z_A and Z_B, Fig. VIII-9. By making the image impedance equal to Z_L no reflection occurs and the impedance of load plus repeater is the same as if no repeater were present. The output current, however, is increased over the input, giving gain. The circuit transmits in either direction with the same gain.

Z_I = Image impedance

$$Z_I = \sqrt{Z_A Z_B}$$

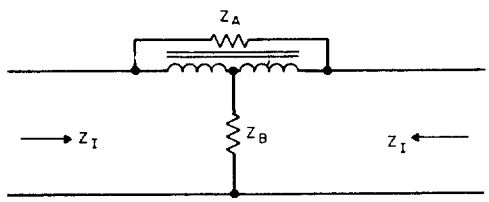


Fig. VIII-9

$$\text{Attenuation} = 20 \log_{10} \frac{1 - \sqrt{\frac{Z_A}{4Z_B}}}{1 + \sqrt{\frac{Z_A}{4Z_B}}}$$

Now if series and shunt negative admittances are inserted in the bridged T structure of value $-NZ_0$ and $\frac{-Z_0}{N}$, Fig. VIII-10.

Z_0 = Image impedance,

$$\text{and gain in db} = 20 \log_{10} \left| \frac{1 + \frac{N}{2}}{1 - \frac{N}{2}} \right|$$

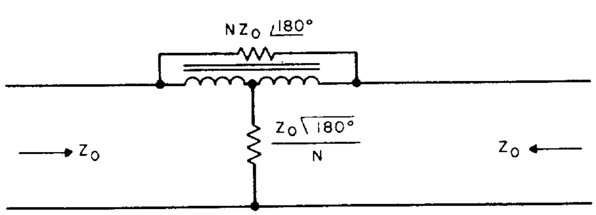


Fig. VIII-10

Thus by making both series and shunt negative impedance have the same phase angle as the desired image impedance and by using the same ratio, N, to determine the magnitude of the series and shunt negative impedances, a structure can be obtained with no impedance mismatch to the line and a gain determined by the value of N.

However, it is not necessary to make both series and shunt negative impedances have the same phase angle as the desired image impedance. In Fig. VIII-9, $Z_I = \sqrt{Z_A Z_B}$ or

$$|Z_I| \angle\theta = \sqrt{|Z_A|\,|Z_B|}\; \angle\frac{A + B}{2},$$

only the ***sum*** of angles A and B of impedances Z_A and Z_B need be made equal to twice the angle of the desired image impedance. Thus $\angle A$ and $\angle B$ do not have to be alike, provided their sum equals twice the desired angle of the image impedance. Also, the series and shunt converters shown in Fig. VIII-4 and VIII-6 do not need to use a center-tapped transformer to obtain the desired feedback. Push-pull type circuits can provide the feedback paths of the proper phase and have advantages in the cancellation of even harmonic distortion products. They also have higher output for a given transistor rating.

However, a transformer is used to couple the circuit to the cable pair. It removes dc supervisory voltage from the negative-impedance circuit and permits dc pulsing on the circuit. A balancing inductor is used on the network side of the converter to maintain stability by providing a lower impedance at this point, over a very wide frequency band, than that at the line terminals.

Capacitors C_1 and C_2 provide the feedback connection and have sufficiently large capacitance to have negligible impedance over most of the voice-frequency range.

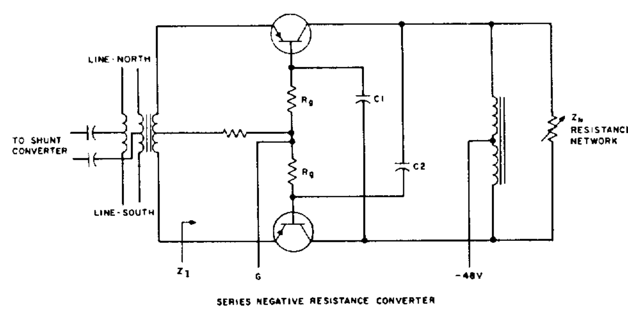


Fig. VIII-11

In the preliminary analysis of the transistor-converter it was assumed that all signal current flowed through the emitter and collector with none flowing in the base circuit. Actually the emitter and collector currents can differ by a few per cent. The negative impedance looking into the line terminals is more accurately given by

$$Z_{In} = (1\text{-}2\alpha)Z_N + (1\text{-}\alpha)2r_b$$

where r_b is the base resistance of the transistor and the impedances of C_1 and C_2 are small. The α of good transistors varies between 0.95 and 1 so that the conversion factor is dependent on the value of transistor α. This may be of small consequence where each individual repeater circuit is adjusted separately, but where a closely reproducible negative impedance is desired for a given value of the network resistance, it imposes close limits on the transistor α characteristic and the variation of this factor with time.

In some typical networks, for loaded cable use, a change in α from 1 to 0.95 changed the ratio of $\frac{Z_{In}}{Z_N}$ from 1 to 0.878.

These variations can be markedly reduced by a tandem, or double-transistor, arrangement which returns a very large percentage of the base current back to the emitter to collector circuit of transistor 1.

The arrangement is as follows:

Each transistor is replaced by a compound transistor in which the base current of the first transistor is returned through the emitter-collector circuit of transistor 2 to the desired path.

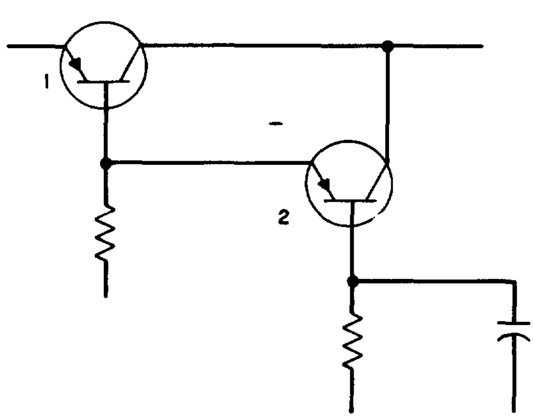


Fig. VIII-12

The losses in base current are now a function of $(1\text{-}\alpha_1)$ $(1\text{-}\alpha_2)$ which is much smaller than the $(1\text{-}\alpha)$ obtained with a single transistor. As a result, the change in conversion factor, that is $\frac{Z_{In}}{Z_N}$ for a variation in transistor α from 1 to 0.95, is only from 1.000 to 0.995. With a single transistor this much variation in α would result in the impedance conversion ratio of 1 to 0.878. For the compound circuit an α of 0.9 for the transistors results in a conversion ratio of 0.987.

Thus by means of the component arrangement and at the price of twice the number of transistors, the initial requirements on α of the transistors can be relaxed, the effects of changes in α with time should be very small, and above all, the repeater settings can be closely reproduced from unit to unit.

The methods for coupling the negative-impedance converters to the line required consideration. The series converter is coupled to the line through the line transformer. This separates the converter circuit from direct connection with the line, permits operating the converter and network at optimum impedance levels, and allows dc pulsing and supervision to pass through the transformer primary with only minor effects due to the converter circuit. The ratio of this transformer used in the E6 converter is 1:9 on an impedance ratio basis with the low windings in series with the line.

The shunt converter is bridged across the pair at the midpoints of the line transformer primary windings. Direct current paths are not permitted here because of dc signaling and supervision requirements. The initial approach was to insert two large capacitors in the line leads to block direct current but permit speech currents to pass to the converter. This was a difficult compromise since large, low-impedance coupling capacitors degrade dc loop pulsing while small capacitors change the negative impedance of the converter, especially at the low-frequency end of the voice band. The use of a transformer and a single blocking capacitor permits reducing the space occupied by capacitors and has less effect on dc pulsing. In addition, transformers isolate the shunt network and its paths from the line pair to battery and ground. The transformer coupling gives a high degree of isolation from the effects of power-induced longitudinal volt-

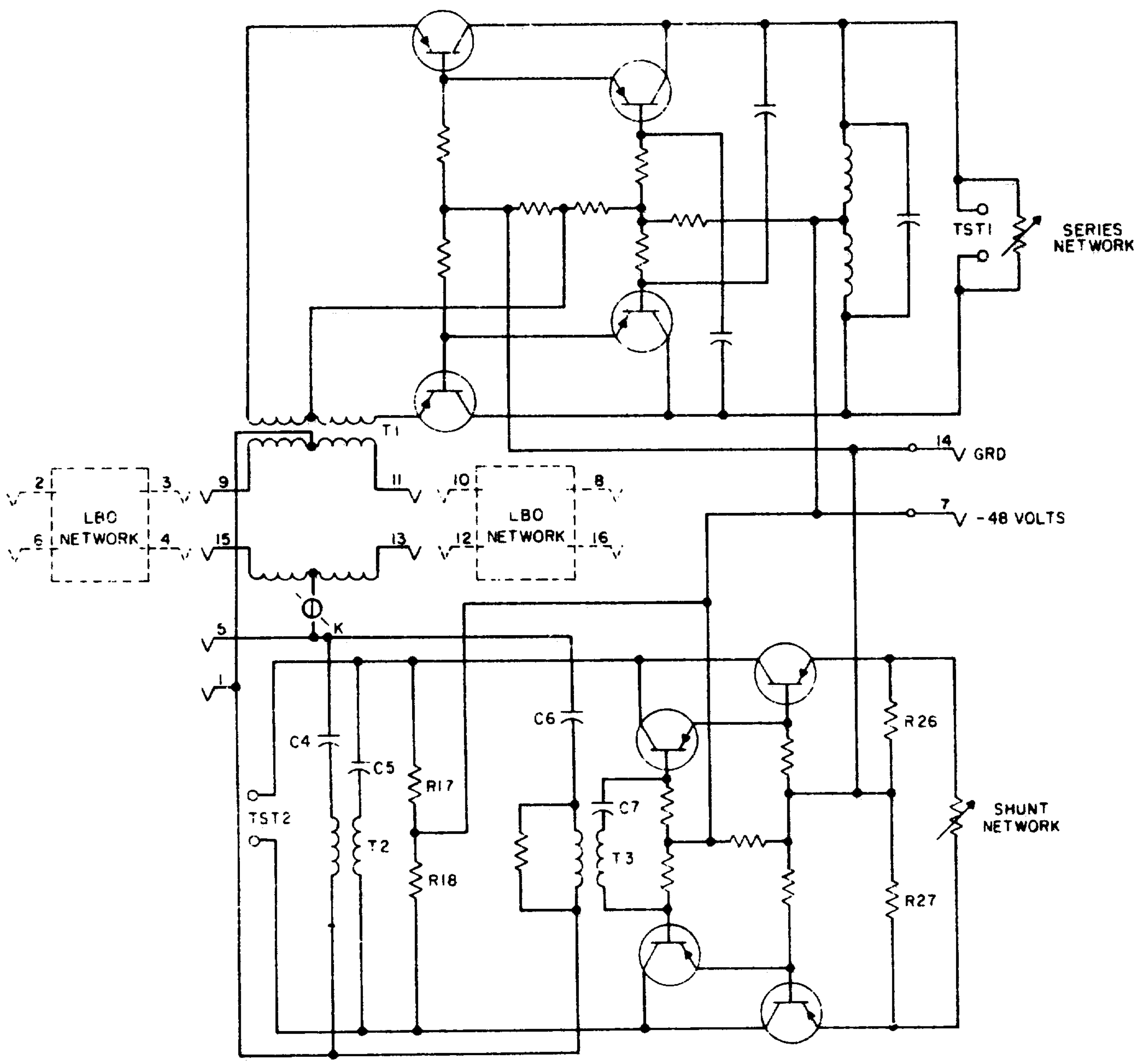

T1
SERIES NETWORK
TST1
14
GRD
7
-48 VOLTS
2
3
6
4
LBO NETWORK
9
15
11
13
10
8
12
16
LBO NETWORK
5
1
K
C4
C5
R17
R18
T2
TST2
C6
C7
T3
R26
R27
SHUNT NETWORK

Fig. VIII-13

ages, which in a small percentage of lines may reach values measured in tens of volts. Lightning-induced surges may reach values of 350 to 500 volts before the carbon protector blocks break down. The transformer coupling is valuable in keeping their effects to a minimum.

The complete diagram of the E6 repeater is shown in Fig. VIII-13 with two 1:1 transformers used to couple the shunt converter to the line coil midtaps.

Obtaining the Desired Image Impedance

The converters so far described would present nearly pure negative resistances at the line terminals for pure resistance values connected in the networks. Since the image impedance of the bridged T arrangement is $Z_I = \sqrt{Z_A Z_B}$ this would give a pure resistance image impedance to the complete gain unit. Suppose, for example, the image impedance value is made 900 ohms. This is to be matched against usual compromise hybrid networks of 900 ohms in series with 2 mf used in exchange offices. The result would be rather poor return loss or high reflection due to the repeater impedance mismatch especially at low frequencies. In addition, the following difficulties would occur:

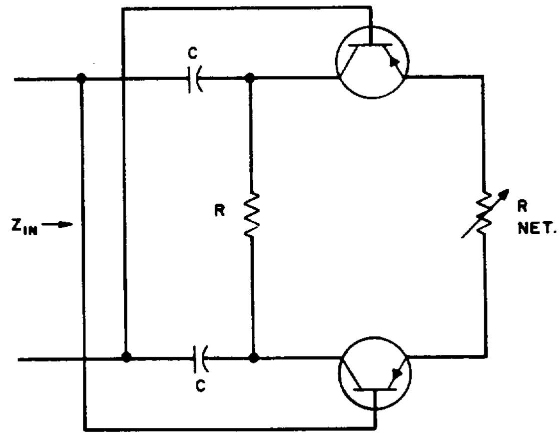
(1) It is difficult to build out or transform loaded line impedances to pure resistance values.

(2) The gain frequency response of the repeater and LBO combination is poor.

(3) The resistive shunt arm degrades dc loop signaling.

One method to obtain the desired complex image impedance is to use complex impedance networks. This complicates the network problem since not only must the network resistance values be adjustable, but also, capacitance or possibly inductance components must also be adjustable. Such a requirement would remove most of the advantages of the line-building-out approach.

Study of the problem has indicated that the desired 900-ohm plus 2-mf image impedance can be obtained by operating the series converter to provide pure negative resistance and operating the shunt converter in a manner to provide the desired phase angle in its negative impedance. This phase shift is accomplished by a ***fixed*** R and C circuit in the feedback path. This is shown by the simplified diagram in Fig. VIII-14, in which the desired phase as a function of frequency is obtained with only resistance network components.



E6 SHUNT CONVERTER

Fig. VIII-14

$$Z_{IN} = \frac{-R_N(R_1 - 2jX)}{R_1 - R_N} = -k(R-2jX)$$

In the complete diagram of the E6 gain unit in Fig. VIII-15, the phase shifting capacitors are C_6 and C_7 and resistors are R_{17} and R_{18}.

LBO Networks

The impedance of loaded cable pairs is by no means a fixed value. It depends on frequency, length of endsection, and cable conductor gauge.

Fig. VIII-16 shows the real and imaginary components of input impedance for 19- and 22-gauge cable circuits which are loaded H88. The mutual capacitance of these pairs is 0.082 uf/mile and the cutoff frequency, which is the infinite loss point, is about 3480 cps.

Fig. VIII-17 shows the variation in impedance of 24-gauge loaded cable pairs as the length of endsection is increased from zero feet, which is adjacent to loading coil, to full section which is 6000 feet from a loading coil. In this plot, the coordinates are the real and imaginary components of the input impedance. Frequency is plotted along the curves as a running parameter.

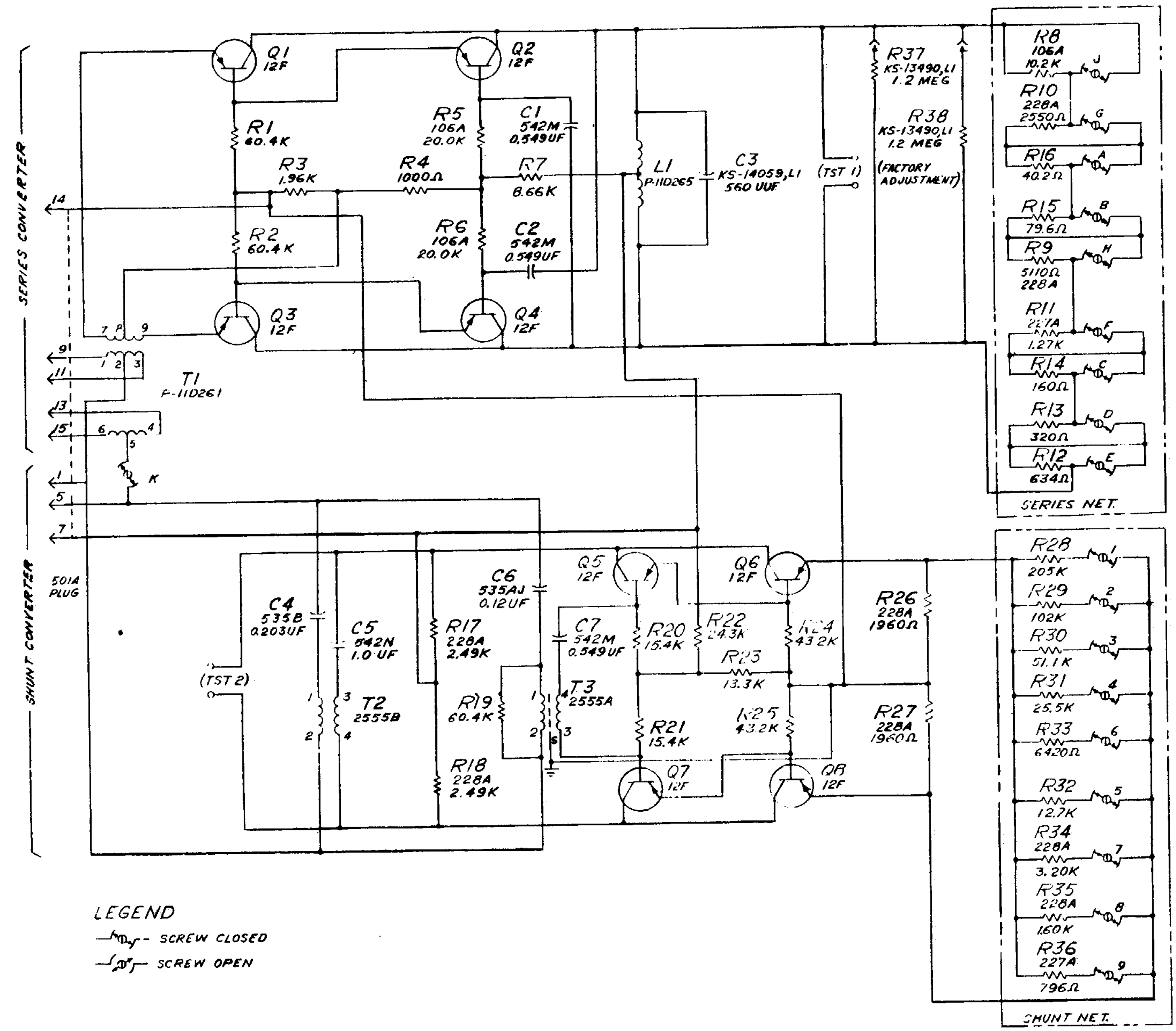

Q1 12F
Q2 12F
Q3 12F
Q4 12F
R1 60.4K
R2 60.4K
R3 1.96K
R4 1000Ω
R5 106A 20.0K
R6 106A 20.0K
R7 8.66K
C1 542M 0.549UF
C2 542M 0.549UF
L1 P-11D265
C3 KS-14059,L1 560 UUF
(TST 1)
R37 KS-13490,L1 1.2 MEG
R38 KS-13490,L1 1.2 MEG
(FACTORY ADJUSTMENT)
R8 106A 10.2K J
R10 228A 2550Ω G
R16 40.2Ω A
R15 79.6Ω B
R9 5110Ω 228A H
R11 227A 1.27K F
R14 160Ω C
R13 320Ω D
R12 634Ω E
SERIES NET.
SERIES CONVERTER
SHUNT CONVERTER
501A PLUG
T1 P-11D261
K
C4 535B 0.203UF
C5 542N 1.0 UF
(TST 2)
T2 2555B
C6 535AJ 0.12UF
R17 228A 2.49K
R18 228A 2.49K
R19 60.4K
C7 542M 0.549UF
T3 2555A
Q5 12F
Q6 12F
Q7 12F
Q8 12F
R20 15.4K
R21 15.4K
R22 24.3K
R23 13.3K
R24 43.2K
R25 43.2K
R26 228A 1960Ω
R27 228A 1960Ω
R28 205K 1
R29 102K 2
R30 51.1K 3
R31 25.5K 4
R33 6420Ω 6
R32 12.7K 5
R34 228A 3.20K 7
R35 228A 1.60K 8
R36 227A 796Ω 9
SHUNT NET.
LEGEND
SCREW CLOSED
SCREW OPEN

Fig. VIII-15

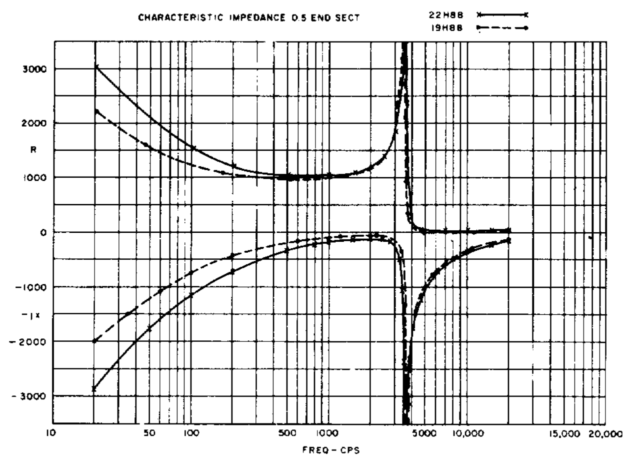


Fig. VIII-16

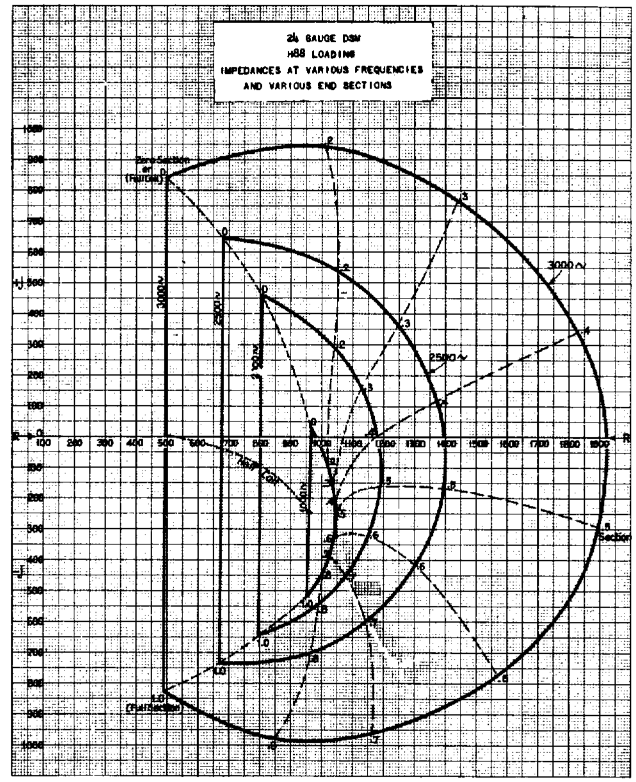


Fig. VIII-17

These large variations in impedance, both with frequency and endsection complicate the job of matching the image impedance of a repeater to loaded-cable impedance. They also account for the complexity of the networks used in E1-, E2-, E3-type repeaters.

The impedance of a full-length endsection of loaded cable, at frequencies above about 1.5 kc can be matched closely by the right-hand part of Fig. VIII-18. Complementary networks can be inserted in series with this network to achieve a constant resistance at the left-hand terminals over a wide frequency band. The high-frequency corrector of the LBO network shown in Fig. VIII-19 is such a complementary network, the value of the components being fixed by the type of loading and the cable capacitance. This part of the network provides a resistive termination above the cable cutoff frequency where the full-section cable impedance becomes very low. The reactance of this portion of the network corrects the reactance of cable impedance at and just below the cutoff frequency.

To accomplish the desired impedance conversion for fixed-image-impedance gain units with a reasonably small number of components, different LBO networks are required for different weights of loading and for different cable capacitance. However, one network will accommodate 19-, 22-, and 24-gauge pairs. The various length endsections encountered in the field are handled by building out with capacitors to approximately full section. Building-out resistors are also used for 22- and 24-gauge cable conductors. Three values of building-out resistors can be connected in combination in the tip and ring conductors of the LBO network adjacent to the cable. These resistors are not usually required for 19-gauge cable pairs.

The remaining part of the LBO network is the low-frequency corrector which is largely effective below 1000 cps. At low frequencies, both the resistive and reactive components of cable impedance rise in value and require correction. The capacitors in this branch of the network are included to prevent a dc path from the tip to the ring conductors. They, unfortunately, do degrade dc pulsing and other dc loop signals. Their value is therefore made as low as will do an acceptable job of impedance correction. Since the increase in cable impedance at low frequencies is least with 19-gauge cable, the 19-gauge low-frequency corrector has the highest impedance and the least effect. The corrector for 22 gauge has lower impedance and a larger correcting factor while the 24-gauge corrector is the lowest impedance.

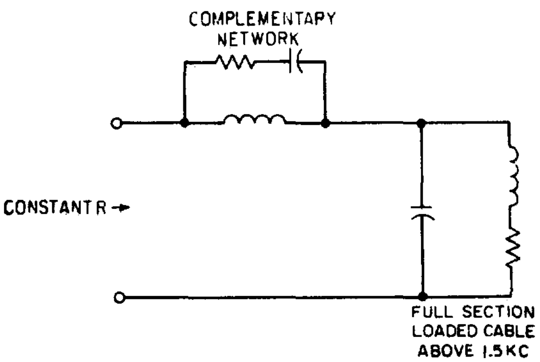
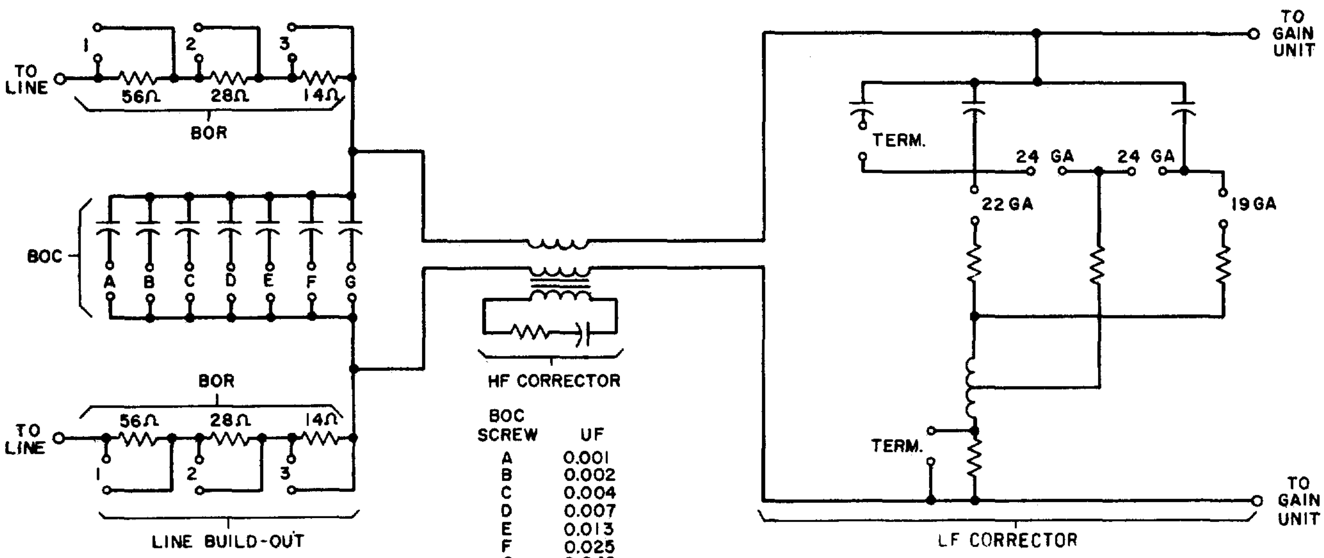


Fig. VIII-18

When the LBO is used with intermediate E6 repeaters, less than the full low-frequency correction is used. This is done because there are then two LBO networks in the line and these have an adverse effect on both signaling and loss. Since maximum return loss is not usually required at intermediate repeater locations, a somewhat higher impedance can be used for the low-frequency corrector than if full correction were necessary.

The increasing shunt loss due to the low-frequency corrector, which occurs at low frequencies, is not particularly harmful. Loaded cable pairs tend to have lower loss at these frequencies than at midband so that the shunt corrector equalizes the transmission loss.



BOC SCREW	UF
A	0.001
B	0.002
C	0.004
D	0.007
E	0.013
F	0.025
G	0.049

830A LINE BUILDING-OUT NETWORK

Fig. VIII-19

CHAPTER IX

EFFECT ON SIGNALING RANGES

Nonloop Signaling

The range-reducing effects of E6 repeaters are largely confined to dc loop signaling circuits. The effect of the E6 repeater on audio-frequency signals such as single frequency (SF), multifrequency key pulsing (MFKP), or push-button dialing is beneficial since these signals are amplified to the same extent as speech signals.

Composite (CX), DX, and simplex (SX) signaling circuits use polar transmission and are only slightly impaired by E6 repeaters.

DC Loop Signaling and 20-cycle Ringing

The E6 voice repeater does not interrupt the continuity of the wire line pairs, so dc supervision and 20-cycle ringing can be passed through the repeaters without the need for auxiliary bypass equipment, up to a maximum loop current of 60 ma. For loop currents larger than this value use E23 repeaters, which are capable of passing 100 ma, or pad down the current.

A table below, headed "Summary of Range Effects in Loop Signaling with E6 Repeaters," gives all the information needed in considering dc supervision ranges. The shunt converter of the E6 repeater (like the E3 part of the E23) bridges capacitance across the pair and distorts pulse signals in a complex manner depending on the length and resistance of cable pairs, the type of signaling system, and the adjustment of the relays in that system. This reduction in range is covered in Tables A through F (attached). In general, the distortion caused by the E6 repeater is within operating margins for panel-call-indicator (PCI) signals, for revertive pulsing into crossbar offices (but not into panel offices), and for dial pulsing into crossbar offices.

This distortion does not permit operation of certain revertive pulsing into panel offices and certain types of dial pulsing into SxS offices. The alternatives are (1) the use of an E2 repeater alone which will not, in general, meet VNL +2 db net loss objectives, or (2) the use of V3 repeaters equipped with signal bypass equipment.

One E6 repeater on a trunk reduces the latter's 20-cycle ringing range by 400 ohms and two E6's reduce it by 750 ohms.

Effect of Building-out Resistors in LBO Network

With the E6 repeater, each cable pair is built out to nearly a full endsection (5800 feet) by the use of bridged capacitors which are part of the LBO network. The endsection may also be built out with resistors when the repeater is used on 22- and 24-gauge (rarely on 19-gauge) cable pairs to give improved return loss. The use of these building-out resistors depends on whether the repeaters are used on toll connecting trunks, and whether the highest return loss is needed. If the repeaters are at the distant (class 5) end, building-out resistances may not be necessary, but when located in the class 4 office they will be needed. For preliminary engineering purposes it can be assumed that the average build-out is 3000 feet at each cable end. This adds 100 ohms for 22-gauge cable pairs, or 150 ohms for 24-gauge cable pairs. The building-out resistors are not needed on 19-gauge cable pairs. In critical cases, the actual amount that the trunks must be built out can be computed from a knowledge of the actual end-section length. In the case of 22-gauge cable pairs, this added resistance will be 32 ohms for each 1000 feet less than a 5800-foot endsection, less resistance in the LBO network(s) and gain unit. For 24-gauge cable it will be 52 ohms for each 1000 feet less than 5800 feet, less resistance in the LBO network(s) and gain unit.

SUMMARY OF RANGE EFFECTS IN LOOP SIGNALING TRUNKS WITH E6 REPEATERS

	EFFECTIVE INCREASE IN LOOP RESISTANCE — OHMS*		
	1 TERM. E6	2 TERM. E6s	1 INT. E6
Supervision	65	130	90
20-cycle Ringing	400	750	400
Pulsing (PCI, RP, & DP)	(See attached Tables A-F)		

* Plus LBO build-out to 5800-foot endsection(s).

LOOP RESISTANCE OF BUILDING-OUT RESISTORS IN 830 NETWORK

TERMINALS	RESISTANCE OHMS
1 & 1	28
2 & 2	56
3 & 3	112

Attached:
Tables A-F

TABLE A

PANEL CALL INDICATOR PULSING TRUNKS

Terminal Circuits		Conductor Loop Range		Rating for Repeaters	
Outgoing	Incoming	Miles	Ohms	1-E6	2-E6
Relay-type Pulse Generator	Xbr Tandem Sender	30	2640	A	A
	Panel Tandem Sender	30	2640	A	A
	Manual Control	30	2640	A	A
Sequence Switch-type Pulse Generator	Xbr Tandem Sender	30	2640	A	A
	Panel Tandem Sender	30	2640	A	A
	Manual Control	30	2640	A	NA

A - Approved
NA - Not approved

TABLE B

REVERTIVE PULSING TRUNKS

Terminal Circuits		Conductor Loop Range		Rating for Repeaters	
Outgoing	Incoming	Miles	Ohms	1-E6	2-E6
Panel or Xbr Sender	Xbr Register or Sender	32	2900	A	A
	Panel Incoming, GCO Direct	12	1300	NA	NA
	Panel Incoming, GCO Repeating	20	2000	NA	NA
	Panel Incoming, BCO Short Range	14	1645	NA	NA
	Panel Incoming, BCO Long Range	24	2700	QA[1]	NA
	Panel Incoming, GCO Repeating Including Improved Balance Circuits	20	2000	NA	NA
	Panel Incoming, BCO Short Range	14	1645	NA	NA
	Panel Incoming, BCO Long Range Unbalanced	24	2700	QA[1]	NA
	Panel Incoming, BCO Balanced Circuit	32	3135	QA[2]	QA[3]

A - Approved
NA - Not approved
QA - Qualified approval
1 - With a maximum range of 16 miles
2 - With a maximum range of 28 miles
3 - With a maximum range of 20 miles

TABLE C

DIAL PULSING TRUNKS INTO XBR OFFICES

Terminal Circuits		Conductor Loop Range		Rating for Repeaters	
Outgoing	Incoming	Miles	Ohms	1-E6	2-E6
Manual Switchboard, DP Sender or SxS Out Repeater	Any "U" Relay Sender	34	3000	A	A
	No. 5 "U" Incoming Register	42	3700	A	A
	No. 5 "WS" Incoming Register	42	4200	A	A
	Tandem "WS" Sender	42	4200	A	A
SxS Out Repeater	No. 5 Bylink Short Range Loop Supervision and Pulsing	14	1200	A	A
	Loop Supervision B/G Pulsing	23	2000	A	A
	B/G Supervision and Pulsing	27	2400	A	A
SD-32087-01	No. 5 "U" Bylink Long Range	32	4200	QA[2,3]	NA
SD-32087-01	No. 5 "WS" Bylink Long Range	32	4200	QA[3]	NA
SD-32199-01	Tandem Bylink CAMA SD-27010-01	32	4200	QA[3]	NA

A - Approved
NA - Not approved
QA - Qualified approval
2 - With maximum range of 20 miles of cable
3 - With change in padding resistor strapping information as covered in Issue 2 of SD-32087-01 and Issue 2 of SD-32199-01

TABLE D

DIAL PULSING TRUNKS INTO SXS OFFICES
FROM SXS REPEATERS

Terminal Circuits		Conductor Loop Range	Rating for Repeaters	
Outgoing	Incoming	Ohms	1-E6	2-E6
Battery/Ground Pulsing				
SD-31779-01	SD-30200-01 Selector	1985	A^4	A^4
SD-32008-01	SD-30200-01 Selector	1900	A^4	A^4
SD-31147-01	SD-30200-01 Selector	2400	A^4	A^4
SD-31929-01 Pulse Corrector	SD-30200-01 Selector	1900	A	A
Loop Pulsing				
SD-31428-01	SD-31648-01 Pulse Corrector	3000	NA	NA
SD-31602-01	SD-31602-01 and SD-31648-01 Pulse Corrector	3000	NA	NA
SD-31648-01 Pulse Corrector	SD-31648-01 Pulse Corrector	3000	A	QA^5
SD-31609-01	SD-31542-01 Pulse Corrector	5000	QA^6	QA^6

A - Approved
NA - Not approved
QA - Qualified approval
4 - With adjustment of the outgoing DP repeater (stiffening of (A) relay) to meet specified pulse repeating requirements
5 - With maximum range of 20 miles of cable
6 - With minimum conductor resistance of 2000 ohms (precluding the use of compensating resistance in SD-31542-01)

SD-32184-01 replaces SD-31648-01 and SD-31542-01

TABLE D (CONT'D)

Outgoing Repeater Circuit	Maximum Incoming Conductor Loop to SD-32184-01		
	24- or 26- Gauge Cable	22-Gauge Cable	19-Gauge Cable
	1-E6*	1-E6*	1-E6*
SD-30205-01	1100	1100	1100
SD-30214-01	1100	1100	1100
SD-31428-01	2400	3900	3900
SD-31541-01	4900	4900	4900
SD-31609-01	3900	4900	4900
SD-31648-01	3400	3400	3400
SD-31674-01	1900	1900	1900
SD-31693-01	1900	1900	1900
SD-31699-01	1900	1900	1900
SD-31726-01	1900	1900	1900
SD-31779-01	1900	1900	1900
SD-31842-01	1900	1900	1900
SD-31929-01	1900	1900	1900
SD-32008-01	1900	1900	1900
SD-32184-01	4900	4900	4900

Note: All values are tentative.

* Maximum conductor loop shown includes 100 ohms for each E6 repeater.

TABLE E

DIAL PULSING TRUNKS INTO SXS OFFICES FROM SWITCHBOARDS AND SENDERS

Terminal Circuits		Conductor Loop Range	Rating for Repeaters	
Outgoing	Incoming	Ohms	1-E6	2-E6
Manual SD-15346-01, or Senders Loop Pulsing	SD-30974-01	2000	A	A
	SD-31747-01 2-way	2000	A	A
	SD-31874 2-way	2000	A	A
Senders Loop Pulsing	SD-31648-01 Pulse Corrector	3000	A	QA[8]
Senders B/G Pulsing	SD-30200-01	1900	A	A
Senders B/G Pulsing	SD-31779-01 SxS Tandem	1900	A	A

A - Approved
QA - Qualified approval
8 - With maximum range of 20 miles of cable

TABLE F

DIAL PULSING TRUNKS INTO SXS OFFICES FROM TOLL

Terminal Circuits		Conductor Loop Range	Rating for Repeaters	
Outgoing	Incoming	Ohms	1-E6	2-E6
Toll Completing Repeated Dialing: SD-55101-01, SD-55255-01, and SD-55346-01	SD-30974-01 Repeater	2000	A	A
	SD-31747-01 2-way	2000	A	A
	SD-31723-01 AB Toll Train Selector	2000	A	A
	SD-31841-01 Toll Train Selector	2000	A	A
	SD-31856-01	2000	A	A
	SD-31874-01 2-way	2000	A	A
	SD-31648-01 Pulse Corrector	3000	A	QA[8]
Intertoll Dialing Completing: SD-55243-01, SD-55301-01, and SD-64473-01	SD-30974-01 Repeater	2000	QA[9]	NA
	SD-31747-01 2-way	2000	QA[9]	NA
	SD-31723-01 AB Toll Train Selector	2000	QA[9]	NA
	SD-31841-01 Toll Train Selector	2000	QA[9]	NA
	SD-31856-01	2000	QA[9]	NA
	SD-31874-01 2-way	2000	QA[9]	NA
	SD-31648-01 Pulse Corrector	3000	QA[10]	NA

A - Approved
NA - Not approved
QA - Qualified approval

8 - With maximum range of 20 miles of cable
9 - With maximum range of 1700 ohms
10 - With maximum range of 24 miles of cable